

22 26 40 61 64

# ELEKTOR ELECTRONICS

64 RISC COLUMN SOFTWARE  
66 IC SUPPLY ADDRESS

THE INTERNATIONAL ELECTRONICS MAGAZINE  
FEBRUARY 1993

UK £2.25

## WATT - HOUR METER

U - 2400 NiCd Battery  
Charger

RF Attenuators

Multi - user satellite  
TV reception

New Column :  
DX Television

I<sup>2</sup>C Optocard

Digital Audio  
Enhancer





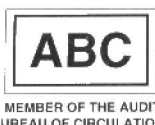
## In next month's issue

- 4 Mbyte printer buffer insertion card - Part 1
- Linear sound pressure meter
- World band radio
- 8032 application notes
- Experimental HF ferrite loop transmitting antenna
- Electrically isolated RS232 interface
- Antenna construction
- Watt-hour meter - Part 2
- 1.2 GHz multifunction frequency meter - Part 4
- Figuring it out - Part 3

## Front cover

In these days when, more than ever, we watch our bank accounts and the environment, it is useful to be able to monitor the energy consumption of the many electrical appliances found in most modern households. The watt-hour meter presented this month on page 14 may prove very helpful in that aim. It can, however, also monitor the energy supplied by a solar panel, as shown in the photograph, or the charging of a battery.

Copyright © 1993 Elektor BV



## AUDIO & HI-FI

- 32 PROJECT:** Digital-audio enhancer  
Design by T. Giesberts

## DESIGN IDEAS

- 26** RF attenuators  
by Joseph J. Carr

## COMPUTERS & MICROPROCESSORS

- 64 PROJECT:** I<sup>2</sup>C opto/relay card  
Design by J. Ruiters

## GENERAL INTEREST

- 22 COURSE:** Figuring it out - Part 2  
By Owen Bishop
- 52 PROJECT:** Digital audio-visual system - Part 4 (final)  
Design by A. Rietjens

## POWER SUPPLIES & BATTERY CHARGERS

- 40 PROJECT:** U2400B NiCd battery charger  
Design by U. Bangert and W. Ernst

## RADIO, TELEVISION & COMMUNICATIONS

- 8** Multi-user satellite TV reception  
By P. Schrama
- 50** DX Television  
By Keith Hamer and Garry Smith

## SCIENCE & TECHNOLOGY

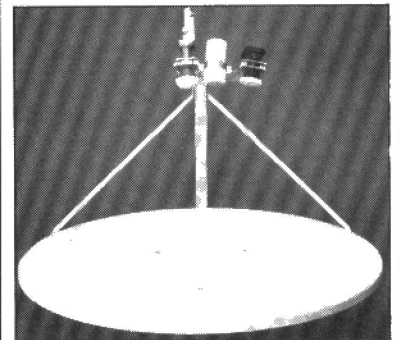
- 46** A possible mechanism for the effects of electromagnetic fields on biological cells  
By Dr K.A. McLauchlan, F.R.S.

## TEST & MEASUREMENT

- 14 PROJECT:** Watt-hour meter - Part 1  
Design by M. Ohsmann
- 67 PROJECT:** 1.2 GHz multifunction frequency meter - Part 3  
Design by B. Zschocke

## MISCELLANEOUS INFORMATION

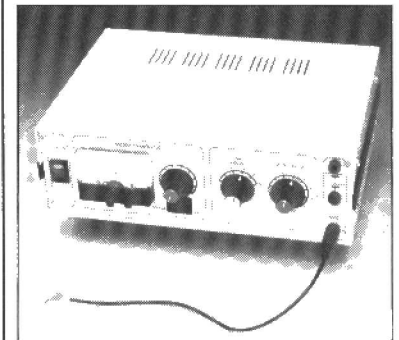
Electronics scene **5-6**; Readers' letters **60**; Events **60**;  
Switchboard **61**; Readers' services **70**; Terms of Business **72**;  
Buyers' guide **73**; Index of advertisers **73**



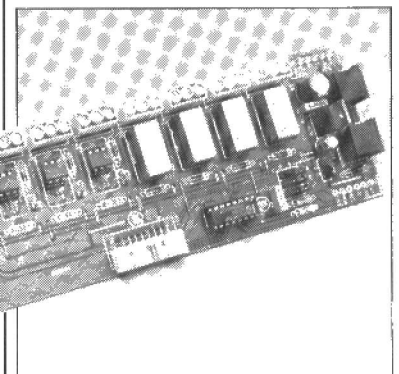
Multi-user satellite TV reception  
p. 8



Watt-hour meter - p. 14



U2400B NiCd battery charger  
p. 40



I<sup>2</sup>C Opto/relay card - p. 64



# ELECTRONICS SCENE

## GOVERNMENT POLICY ON HIGH TECHNOLOGY SHOULD ENCOURAGE, NOT LEGISLATE

In his 1992 NEC Mountbatten Memorial Lecture at the Institution of Electrical Engineers, Sir Leon Brittan, Vice President of the European Commission, said that every government must have a policy on high technology, but too much policy is a waste of time. Influence rather than legislative control should be the order of the day. He stressed the importance of the EC's role in complementing national effort in the area of high technology, in establishing framework programmes for future research, in encouraging the development of technical standards and in ensuring 'level playing fields' of competition.

He continued to say that there has to be a legislative framework within which firms and service providers can operate; and that is the business of government to lay down. But beyond setting the ground rules, regulations, be they from the Community, Member States or even regions in some countries, have to be extremely cautious. Going beyond the ground rules means making choices about technological developments that few of us are capable of making.

Sir Leon also criticized those sectors that seek to protect the European high-tech industry from the cold winds of international competition. He said that exposure to competition not only does no harm, it actually does good. It ensures that customers have a choice of supplier and that itself ensures that there is pressure on suppliers to keep prices down and quality and services up. Where protection is allowed, the quality, service and the price are all at risk.

He continued by querying whether we really need to have companies capable of providing for all our needs. He said he did not believe that the thrust of creative research and the slog of product development and marketing are in any way enhanced by a protectionist environment or by the meddling of those outside the industries concerned. He said that the combative scenario of Europe versus the USA versus Japan is not only unhelpful, but also out of date. He felt it was not a matter of European companies surrendering to the suffocating embrace of the Japanese or the yielding to the backslapping bonhomie of the Americans, but rather a matter of using intelligently the resources that different companies have so that at the end of day a better product at a lower price is available for the consumer.

Sir Leon ended by reiterating his support of the judicious 'hands off' policy approach to European high-tech industry.

## EARLY LAUNCH FOR EUTELSAT II-F5

In response to increasing requests for satellite capacity, EUTELSAT has decided that the fifth EUTELSAT II satellite will be launched as soon as possible. Construction of the satellite will be complete in April.

The four EUTELSAT II satellites already in orbit provide a total of 64 transponders, of which 62 are fully operational or reserved. EUTELSAT II-F5 will enable EUTELSAT in particular to satisfy more requests for business communications between eastern and western Europe, and for leased transponders that are largely used for television transmissions. It will also be needed to provide service continuity for telephony as the EUTELSAT I satellites gradually go into inclined orbit.

By late next year, the full EUTELSAT II system will comprise six satellites at five orbital positions, offering 96 transponders for intra-European communications. The sixth EUTELSAT II will be launched in the second half of next year and will be co-located with EUTELSAT II-F1 at 13°E in order to provide 32 transponders from one orbital position.

**EUTELSAT, Tour Maine-Montparnasse 33, avenue du Maine, 75755 Paris Cedex 15. Phone (33) 1 45 38 47 57.**

## SOLITONS PROMISE NEW ERA IN OPTICAL COMMUNICATIONS

By the end of the decade, international communications will be dominated by special light pulses called optical solitons, according to Professor Nick Doran of Aston University.

The professor says engineers and scientists have found they can produce soliton light pulses able to travel hundreds of kilometres without changing their shape. This gives promise of a new era in optical communications.

In a review of developments, Professor Doran told the Institution of Electrical Engineers—IEE—in London that the optical soliton is the solution to the current problem of light pulses spreading as they travel along optical fibres.

Solitons are likened to the exceptional tidal wave that can travel staggering distances. Such a wave was first noticed by Scott Russell while riding his horse in Victorian times along the Union Canal in Scotland. He saw a solitary wave created by a barge and followed it many miles. Astounded by the wave's persistence, he spent much of the rest of his life trying to understand it.

Russell did not connect this wave with other examples in nature, nor did he coin the term soliton. It was not until recently that the mathematics was evolved to deal with the non-linear system governing the evolution of Russell's wave.

The major advance was the discovery of particular solutions to some non-linear differential equations. These solutions, called solitons, had some very unusual and precise properties, including the non-dispersiveness that Russell had observed.

Now, communication engineers are learning to create a similar optical wave, at will, to transmit information. The best source of solitons is the erbium-fibre soliton laser. Prof. Doran, who is said to be the UK's leading authority on optical solitons, says of it: "This is a remarkable source of virtually perfect solitons, which is attracting much interest in research laboratories. The latest results are showing some astounding features of this laser in terms of the potential for self-organization and the spontaneous generation of solitons."

## AFFORDABLE VIDEOPHONE FROM MARCONI

The world's first affordable, full-colour motion picture videophone, developed by Marconi Electronics, is expected to be ready for domestic use by the end of the year.

Technical problems and the extra cost of providing vision for telephone callers has so far been a barrier to commercial videophones. Marconi have perfected a new technology, resulting in the Relate 2000 Videophone which will cost less than £400 and use standard telephone lines. Videocalls will be charged at the same price as telephone calls.

Technologies that Marconi have developed to make the videophone affordable include data compression of audio and video signals, modem technology and integrated camera and display technology.

**Marconi Electronics, The Grove, Warren Lane, Stanmore HA7 4LY.**

## PAYPHONES IN THE ANTARCTIC

British payphones just installed at Scott Base in the Antarctic will provide new international telecom links for scientists and biologists working there. At a latitude of 71°51'S and a longitude of 166°46'E, they are thought to be the world's most southerly payphones.

The payphones are of the type sold to more than 39 territories worldwide by GEC Plessey Telecommunications (GPT).

The Antarctic covers nearly 14 million square kilometres, about the size of the United States and Australia combined. Some 90% of its surface is covered by ice that is 4000 metres thick in places. This volume of about 25 million cubic kilometres represents over 90% of the world's



ice and contains some 72% of its fresh water.

Located at Pram Point on the Hut Point Peninsula of Ross Island, Scott Base, named after the explorer Capt. James Scott, was established in 1957.

#### EURO VIDEOPHONE SERVICE

British Telecom (BT) and five other telecommunications companies from Germany, France, the Netherlands, Italy and Norway have launched joint videophone trials that will lead to users being able to dial up face-to-face meetings between the six countries.

The trials, code-named EVE-2 and likely to last nine months, involve a number of international companies from each country, together using more than 100 videophones. In Britain, they include IBM, Mars, Lucas Automotive, the Highlands and Islands Enterprise, Motorola, and Southampton University.

#### CARRY ON KARAOKE CONTEST

Maplin Electronics and PMI (part of the EMI Recording Group) have organized a national 'Carry On Karaoke Contest'. First prize is a recording session at the Abbey Road Studios—made famous by the Beatles. There are visits to the Abbey Road Studios for the two runners-up plus copies of the PMI Original Karaoke Volume to the next 12 runners-up.

Entry is easy. With every Maplin Home Karaoke set purchased (price £49.95, incl. VAT), there is a free entry form. Entrants to the contest must use a PMI backing tape (there is one in every Maplin Home Karaoke set) and be prepared to attend, if necessary, local, regional and final heats. The contest closes 31 March 1993.

Further information from **Alan Simpson, Maplin Press & PR, 4 Brooklands, London N21 2BZ. Telephone 081 360 1729.**

#### PAT GUIDE FROM SEAWARD

Safety test instrument manufacturer Seaward Electronic has published a new guide to its comprehensive range of portable appliance testers and related equipment.



Seaward's portable appliance tester range has been designed for use by electrical contractors, service companies and other organizations to assist with compliance to Health & Safety legislation, incl. the Electricity At Work Regulations 1989.

The award-winning range comprises six different portable appliance testers for all safety testing requirements, including single and dual voltage instruments and models suitable for testing of IT equipment. The instruments are supported by user-friendly software packages for storage of test records, together with a wide range of accessories.

**Seaward Electronic Ltd, Bracken Hill, South West Industrial Estate, Peterlee, Co Durham SR8 2JJ. Telephone (091) 586 3511.**

#### SAFETY AND EMC

The latest issue of ERA Technology's *Safety and EMC*, the bi-monthly newsletter for designers and suppliers of electrical and electronic products, contains news of the EC's General Product Safety Directive which will come into force in June 1994.

The newsletter outlines the scope of the Directive, the types of product it covers, the exceptions, the definition of a safe product, the obligation of manufacturers and suppliers, the mechanism of compliance and the responsibilities of the member states concerning enforcement. The Directive applies to all consumer products for which there are no specific EC provisions for safety, and covers new, used and reconditioned goods, but exempts second-hand goods sold as antiques or described as being in need of repair. Sample copies of past issues can be obtained from **ERA Technology Ltd, Cleeve Road, Leatherhead KT22 7SA. Telephone (0372) 374151.**

#### NEW VCR FROM GRUNDIG

With the GV250 NICAM long-play VCR from Grundig you no longer have to remember to write programme titles on labels: it can store up to 700 titles (upgradable to 1400 – up to 999 cassettes). No longer are you likely to miss the end of a programme because the tape runs out. No longer do you have to keep your audience waiting while you find the right tape. When you want to watch your favourite film or concert, with the GV250 it's all there at the touch of a button. The hardest function you have to perform is to number your cassettes as you record them. The retail price is £629.99.

**Grundig International Ltd, Mill Road, Rugby CV21 1PR. Phone (0788) 77155.**

Produced and published by **ELEKTOR ELECTRONICS (Publishing)**

**Editor/publisher:** Len Seymour  
**Technical Editor:** J. Buiting

**Editorial & Administrative Offices:**  
P.O. Box 1414  
DORCHESTER DT2 8YH  
England

**Telephone:** (0305) 250 995 (National)  
or +44 305 250 995 (International)  
**Fax:** (0305) 250 996 (National)  
or +44 305 250 996 (International)

**U.K. Advertising Office:**  
3 Crescent Terrace  
CHELTENHAM GL50 3PE  
**Telephone:** (0242) 510 760  
**Fax:** (0242) 226 626

**International Advertising Office:**  
Elektuur BV  
P.O. Box 75  
6190 AB BEEK  
The Netherlands  
**Telephone:** +31 46 38 94 44  
**Fax:** +31 46 37 01 61

**Subscriptions:**  
World Wide Subscription Service Ltd.  
Unit 4, Gibbs Reed Farm  
Pashley Road  
TICEHURST TN5 7HE  
**Telephone:** (0580) 200 657 (National)  
or +44 580 200 657 (International)  
**Fax:** (0580) 200 616 (National)  
or +44 580 200 616 (International)

**Head Office:**  
P.O. Box 75  
6190 AB BEEK  
The Netherlands  
**Telephone:** +31 46 38 94 44  
**Telex:** 56617 (elekt nl)  
**Fax:** +31 46 37 01 61  
**Managing Director:** M.M.J. Landman

**Distribution:**  
SEYMOUR  
1270 London Road  
LONDON SW16 4DH

**Printed** in the Netherlands by NDB, Zoeterwoude

**Overseas editions:**  
**FRANCE**  
Elektor sarl  
Les Trois Tilleuls  
B.P. 59; 59850 NIEPPE  
**Editors:** D.R.S. Meyer; G.C.P. Raedersdorf  
**GERMANY**  
Elektor Verlag GmbH  
Süsterfeld Straße 25  
5100 AACHEN  
**Editor:** E.J.A. Krempelsauer  
**GREECE**  
Elektor EPE  
Kariskaki 14  
16673 Voula - ATHENA  
**Editor:** E. Xanthoulis  
**HUNGARY**  
Elektor Elektronikai folyóirat  
1015 Budapest  
Batthyány u. 13  
**Editor:** Lakatos András  
**INDIA**  
Elektor Electronics PVT Ltd  
Chhotani Building  
52C, Proctor Road, Grant Road (E)  
BOMBAY 400 007  
**Editor:** C.R. Chandarana

**ISRAEL**  
Elektorcal  
P O Box 41096  
TEL AVIV 61410  
**Publisher:** M. Avraham  
**NETHERLANDS**  
Elektuur BV  
Peter Treckpoelstraat 2-4  
6191 VK BEEK  
**Editor:** P.E.L. Kersemakers  
**PORTUGAL**  
Ferreira & Bento Lda.  
R.D. Estefani, 32-1<sup>oo</sup>  
1000 LISBOA  
**Editor:** Jeremias Sequeira  
**SPAIN**  
Resistor Electronica Aplicada  
Calle Maudes 15 Entlo C.  
28003 MADRID  
**Editor:** Agustin Gonzales Buella  
**SWEDEN**  
Electronic Press AB  
Box 5505  
14105 HUDDINGE  
**Editor:** Bill Cedrum



# MULTI-USER SATELLITE TV RECEPTION

This article looks at several options that exist for the distribution of satellite TV signals in small networks. Also, in the face of the formidable increase in the number of programmes that can be received these days, we are hard pressed to have a look at receiver system configurations that allow two or more satellites to be received simultaneously using a single, fixed, dish antenna.

By P. Schrama

**M**OST of the information that has appeared in satellite TV magazines regarding multi-user networks has been confined to reception of the Astra satellite cluster at 19.2 degrees East. However, as many of you will be keenly aware, there is more on the Clarke belt than the two Astra 'birds'. Consequently, many of you will have wondered what can be done in respect of multi-satellite reception as well. In particular, ex-patriates and foreign workers will often be delighted to be able to watch programmes from the 'home front' in addition to those offered by Astra.

Although an outdoor unit with a motor driven dish allows you to aim at any geo-stationary satellite 'within sight', this is not usually a viable solution if more than one user is connected to the system. In a small apartment, for instance, different users may want to watch different programmes on, you

guessed it, different satellites. This is a real problem since not everybody can be allowed to turn the dish as he or she likes — others may hate to see their favourite programme disappearing suddenly from the screen!

In this article we will take reception of the Astra, Eutelsat II-F1 and Eutelsat II-F2 satellites as an example to see what equipment is required to set up a multi-satellite, multi-feed, multi-user receive system based on one, fixed, dish antenna. Further, it is assumed that the receive station is located in Western Europe. However, the principles of multi-feed reception and signal distribution of Ku-band (11-GHz) satellite TV signals are applicable to any other area in the world.

## The latest trend: multi-feeds for co-reception

The term 'multi-feed' refers to a mechanical system consisting of a number of LNCs (low-noise converters) and associated feeds, fitted outside the focal area, or off the main focal axis, of the dish, in accordance with the azimuth (horizontal angle) difference between the satellites in question. A multi-feed thus allows programmes to be received that are not on the satellite to which the dish is actually aimed, but only if the 'co-satellite' is not too far away from the 'main' one. In a multi-feed construction, the position of the LNC is always opposite the direction from which the satellite is received (see

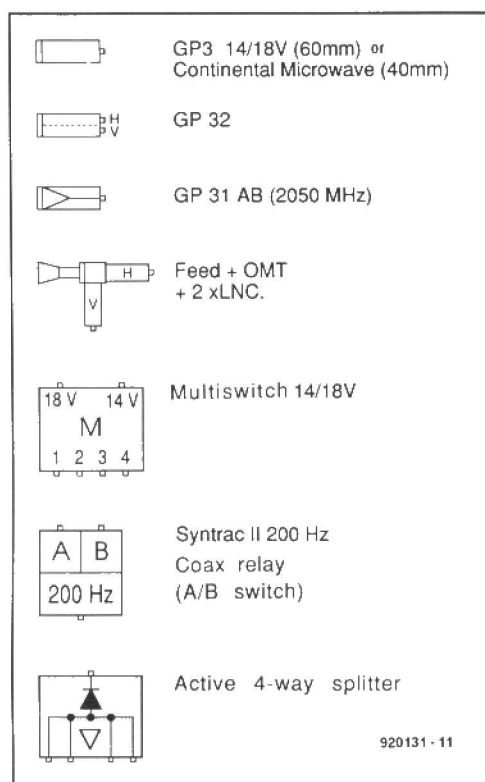


Fig. 1. Overview of the components used in the proposed receive system configurations.

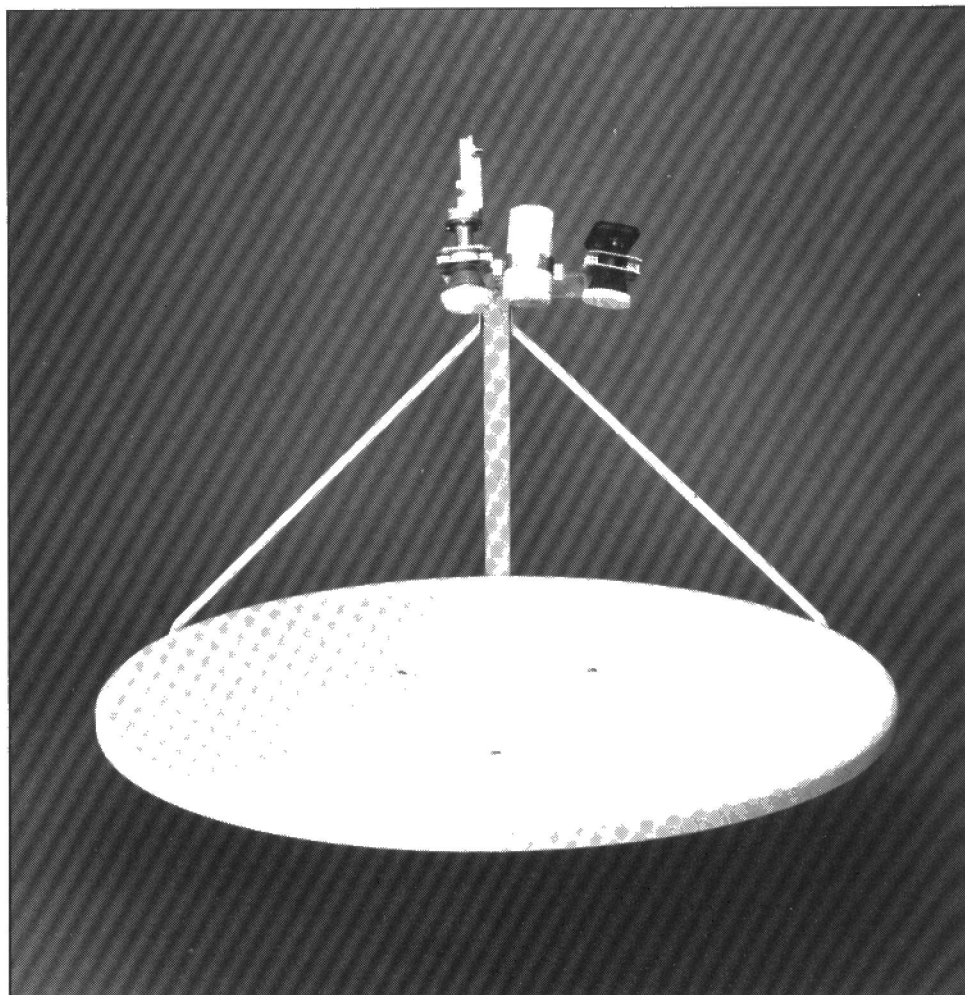


Fig. 2. Sat System 900 dish with three LNCs fitted on to the multi-feed plate.



Fig. 9). This is because the angle of the reflected beam (to the LNC input) is the same as the angle of incidence. In plain words: the dish and main LNC are aimed at one satellite as before, while a second LNC, fitted outside the focal area, 'squints' to another satellite positioned not too far away from the main one.

Because of some physical properties related to the dish geometry, like reduced illuminance, we have to take into account a reduced dish gain for signals caught outside the focal area. The reduced gain is often compensated by using a dish size that is the next larger relative to the size normally required (e.g., 1 m instead of 80 cm, 1.5 m instead of 1.2 m, etc.). Furthermore, the dish size required for multi-feed co-reception depends on the azimuth difference. The gain reduction of a good dish antenna will be roughly 1 dB per 3° of azimuth difference.

In general, the main axis of a dish antenna fitted with a multi-feed LNC cluster is aimed at the weakest satellite. If, for instance, we wish to receive Astra as well as Eutelsat II-F1 or Eutelsat II-F2, a dish size of 85-90 cm is normally required (in Western Europe). If this dish is aimed at one of the Eutelsats, 'squinting' to Astra obviously does not require a larger dish, since 60 cm is usually adequate for this satellite.

Since both Eutelsats (at 10° and 13° East) are normally equally strong, but weaker than Astra, the dish is conveniently aimed at a point in between the Eutelsats. Using a 90-cm dish, reception of these two satellites will still be adequate, since the dish gain reduction will be limited to about 0.5 dB only, caused by an azimuth difference of 1.5° in each direction.

Larger azimuth differences, for instance, between Astra (19.2° East) and Eutelsat I-F4 (7° East) call for larger dishes, not only to compensate the reduced dish gain, but also because the Eutelsat I-F4 beams a much weaker signal into Western Europe. A dish size of 1.2 m is required anyway to receive Belgrade on the Eutelsat I-F4. This size is still sufficient for the reception of Astra at an azimuth difference of no less than 12°. Fortunately, although 12° is very near the limit of what is possible with a 1.2-m dish, such a multi-feed system allows four satellites to be received simultaneously without investing in a motorized outdoor unit (i.e., a polar mount drive).

Azimuth differences smaller than 3° often cause problems with the size and the mounting of the LNC feeds, which then have to be fitted very close to one another. For instance, the azimuth difference is only 2.3° for co-reception of the Astras (1A and 1B) and Eutelsat I-F5 (at 21.5° East). Such a multi-feed is however required for users wishing to view the Zagreb broadcast on the I-F5.

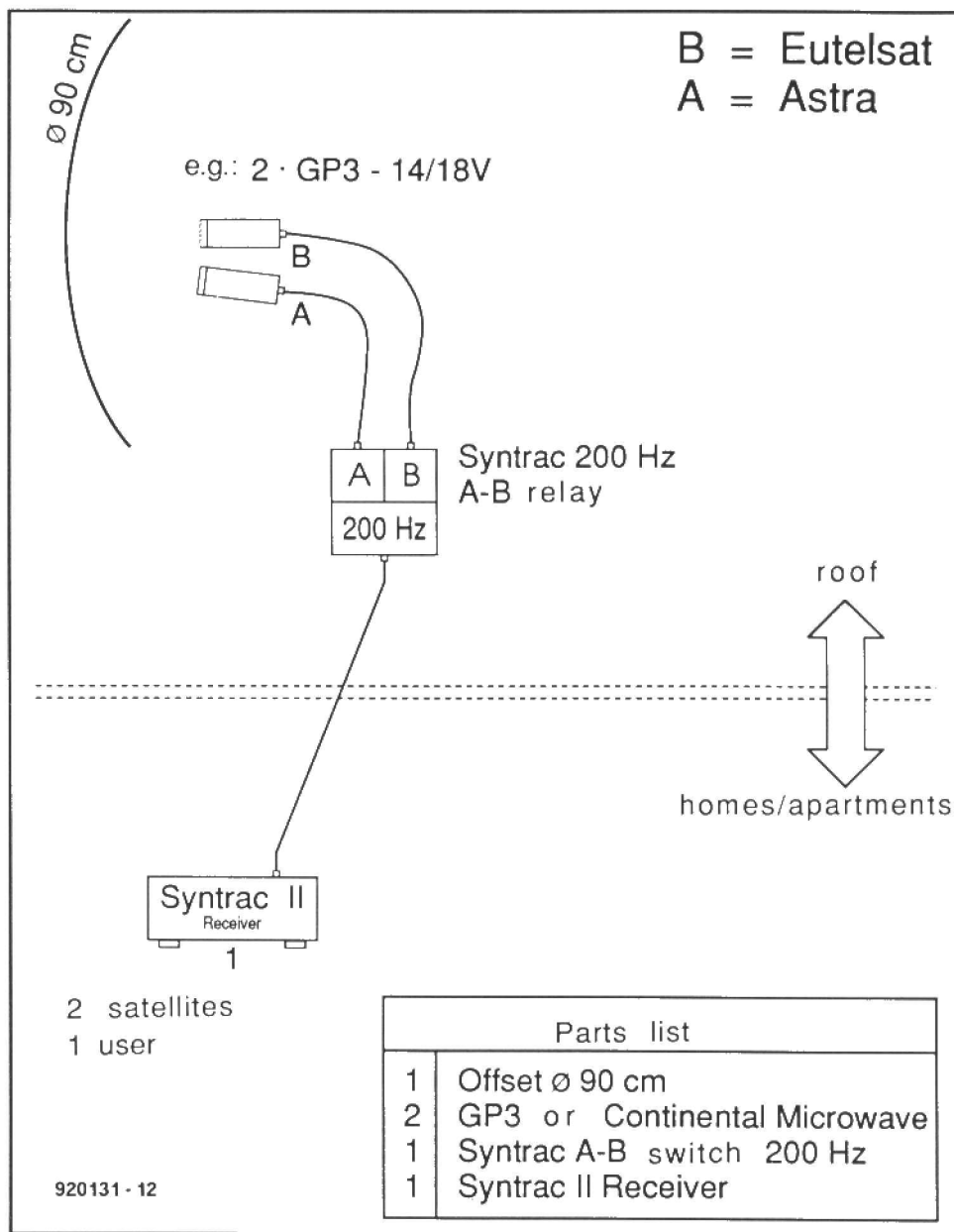


Fig. 3. Two satellites, one user.

If a normal feed horn is used for the weakest satellite, it is often not possible to fit a funnel-type LNC feed close enough to the other one, since this will have an aperture of up to 60 mm. This problem may be solved by using a Marconi LNC with a dielectrical polyrod feed, which is cone-shaped. This type of LNC may be secured directly to the side of the other feed. Thanks to the much smaller diameter of the polyrod feed, it proved possible to receive Astra at an azimuth difference of only 2.3°. However, the HTV Zagreb programme has meanwhile moved to a transponder on the Eutelsat II-F3 at 16° East. This means that the azimuth difference with Astra is now 3.2°. For azimuth differences larger than or equal to 3°, it is possible to use Sharp LNCs also, since these too have relatively small feeds.

As regards the elevation (vertical) angle, this did not appear to require correction in the case of the above examples,

since the differences remain limited to tenths of a degree. Setting the correct elevation angle was found unnecessary since it gave no noticeable improvements.

When a TV receive system for satellite as well as terrestrial broadcasts is to be built from scratch (i.e., a completely new system is installed) it is recommended to use a multiswitch or signal combiner as shown in Fig. 5. A separate power supply for the LNCs is also quite useful in such cases.

## The building blocks

The system descriptions below are based exclusively on modules that are available on the satellite TV market. Some modules may also be available from other suppliers than the ones mentioned. Compatible models from other manufacturers may also exist.

The outdoor unit is based on a 90-cm



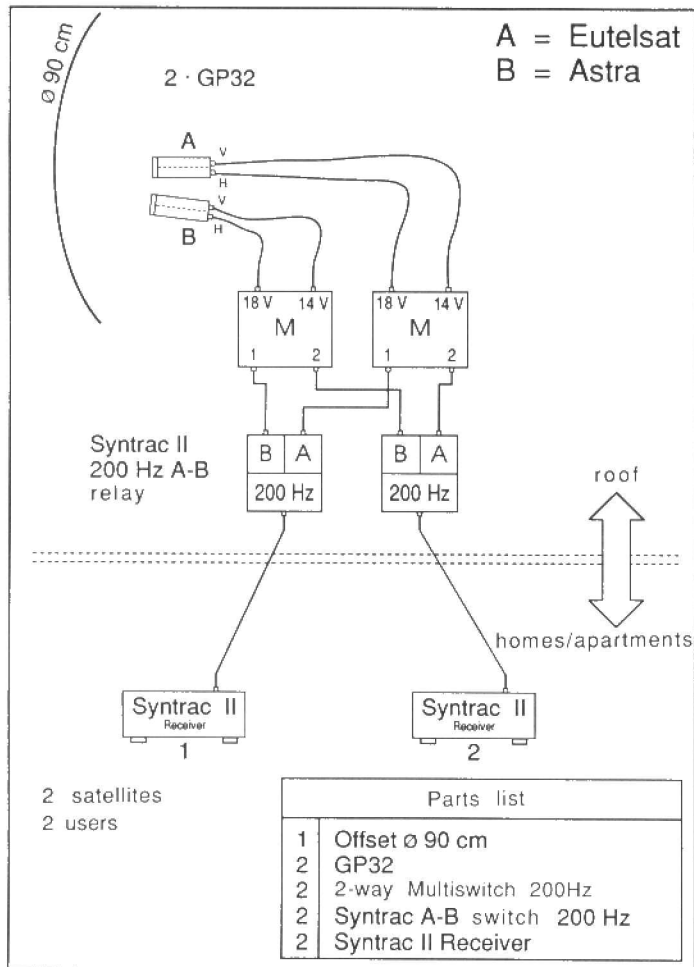


Fig. 4. Two satellites, two users — 'old' configuration.

offset dish supplied by ITS of Bonn, Germany. This dish has a number of constructional characteristics that make it particularly suited to our purpose.

This dish has a feed boom on to which a standard, universal, feed can be mounted. However, it is also possible to mount a multi-feed holder. This holder is a simple base plate with holes in it to secure the different feeds. Apart from the small, low-cost, base plate, this dish does not require special (expensive) mechanical add-ons to realize a multi-feed construction. Small elevation angle corrections (if at all necessary — see above) may be achieved simply by bending the base plate. The feed clamps that can be supplied are suitable for 23 to 40 mm dia. and 60 mm (MTI) feeds.

Figure 1 lists the different LNC types, modules and equipment. In the examples, it is assumed that single-polarity, 14-18 V, LNCs are used, such as the MTI-GP3 or Continental Microwave, which have off-set local oscillators and an extended IF range up to 2,050 MHz (GP 31AB). It is also necessary at this point to discuss some of the special features of the Syntrac-II receiver used in the proposed receive system configurations. A series of this type of receiver has an extended input frequency range of 2,000 MHz, which is a necessary feature

for some of the proposed receive system configurations. The Syntrac-II also has a function known as 'master programming', which enables all settings relevant to a certain channel to be copied to another receiver. The advantages of this feature are evident if it is known that the Astra programme/channel assignment programmed into the receiver by the manufacturer is confused, if not illogical, and is best changed straight away on receipt of the receiver. Assuming that everyone connected to the small cable network has a Syntrac-II receiver, the 'master programming' feature may save a lot of time, since channel re-arranging is required only once, after which the settings can be copied to all users at the flick of a switch.

A further special feature of the Syntrac-II is its ability to switch between two LNCs without having to forfeit the (partly) required 14/18-V controlled multiswitch or polarization selection. Unusually, the LNC switching function is achieved by a relay operated by a 200-Hz signal, which is superimposed on the 14/18 V LNC supply voltage.

The above features make the Syntrac-II a very good choice for use in a multi-feed, multi-user, multi-satellite receive system. Another good receiver offering an extended input frequency range

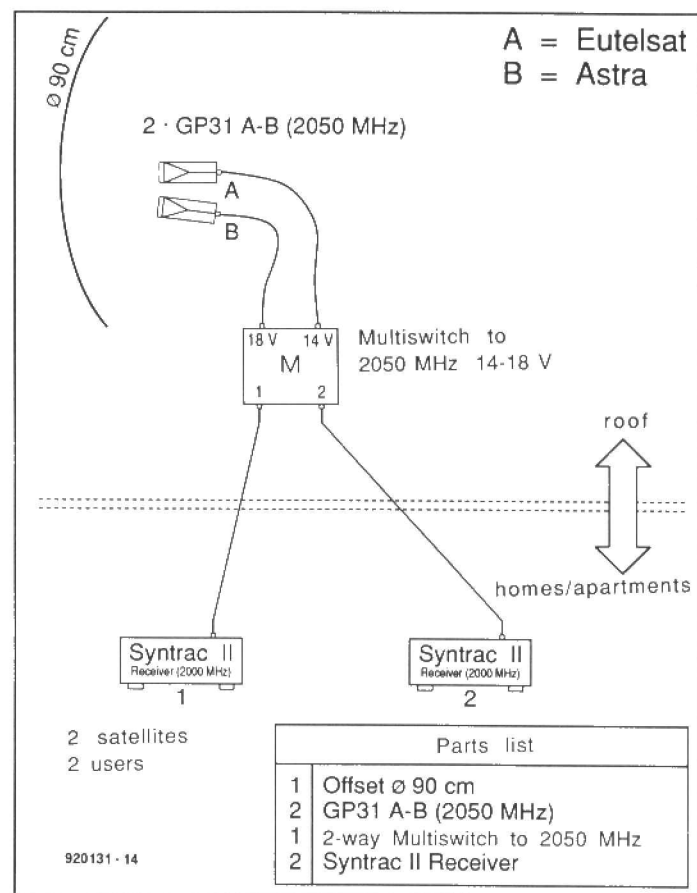


Fig. 5 Two satellites, two users — 'new' configuration using 2,050 MHz components.

(2,050 MHz) is the BX 100 from Zehnder. Unfortunately, this receiver does not supply the 200-Hz signal to control the coax switch. However it can be used without problems in all example configurations where the 200-Hz signal is not used.

If you are an apartment dweller with a permission to fit a small dish on the balcony railing, and the distance to the receiver is only a few metres, the total equipment layout becomes much simpler, and it may be worthwhile to use a satellite receiver with two IF inputs. An example of such a receiver is the inexpensive, widely available CBM-9200 from Citizen, or the PACE MRD-920, which has a built-in D2MAC decoder.

The total size of the installation can be reduced significantly by clever selection of components and cutting down on the number of control lines that would otherwise be required.

#### Two satellites — one user (Fig. 3)

Figure 3 shows a simple example. Converter A or B is selected via the 200-Hz coax relay. The polarization selection on both LNCs is achieved by the 14/18 V control voltage. This configuration may be used, for instance, for the Astra-Kopernikus pair, or the Astra-Eutelsat II-F1/Eutelsat II-F2 pair.



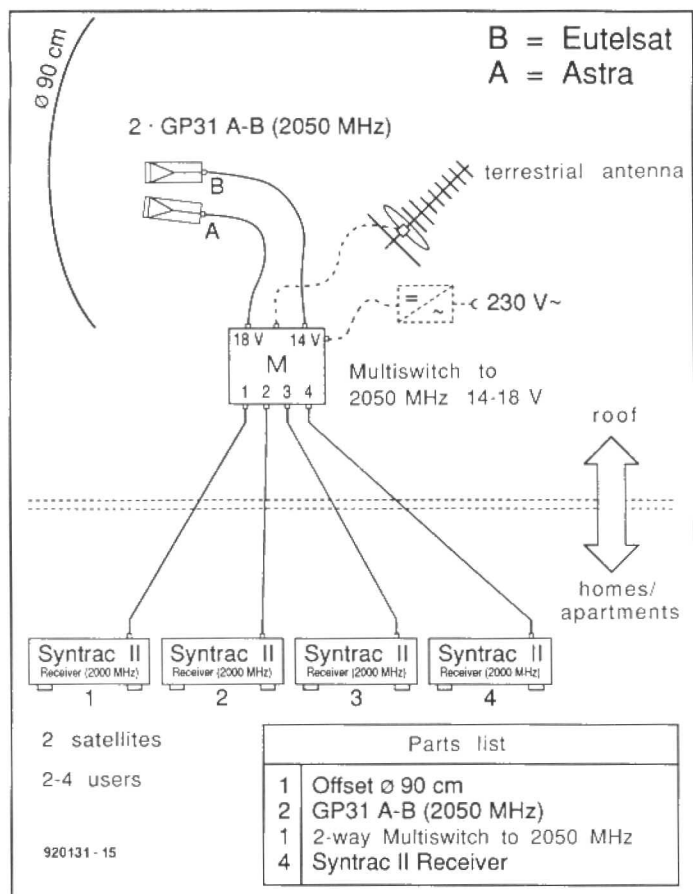


Fig. 6. Two satellites, two to four users. LNCs used are single output split IF range 2050 MHz types.

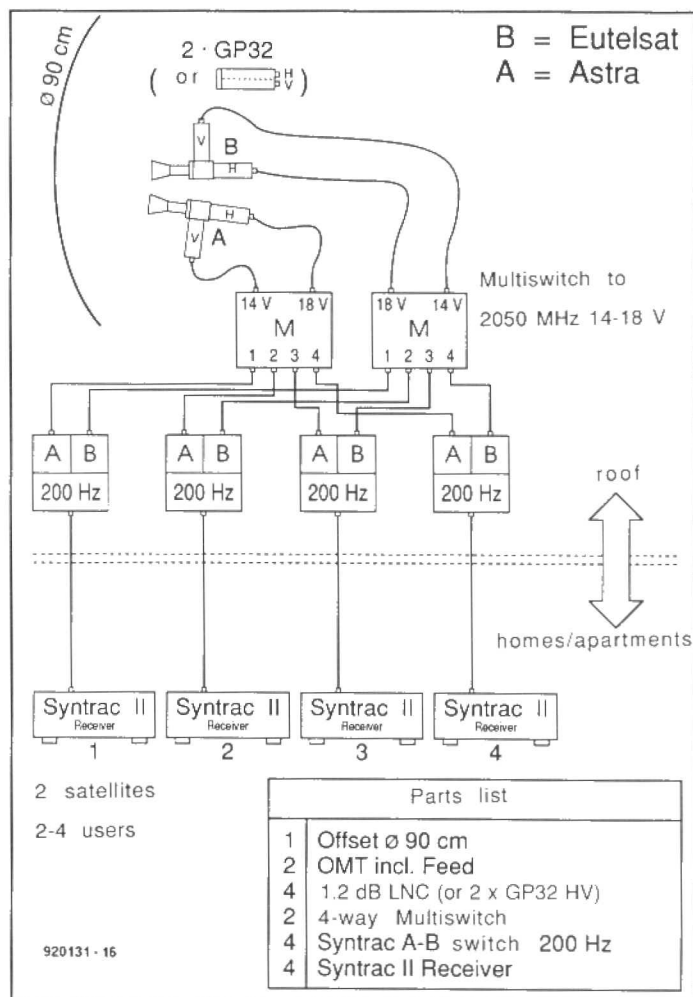


Fig. 7. As Fig. 6, but using four single-polarization LNCs and two OMTs.

Although the interest in the Kopernikus satellite has declined since the start of the Astra 1B in March 1991, many Hi-Fi music lovers will remain keen on receiving the DSR (digital satellite radio) channels packed together on one of the Kopernikus transponders. A DSR programme bundle is, unfortunately, not (yet) available on the Astra. When aimed at the Eutelsat II-F1, the proposed system brings several Turkish, one Arabic and a number of English and French-language programmes on your screen. Among the signals transmitted by the Eutelsat II-F2 are Turkish, Spanish and Italian broadcasts.

#### Two satellites — two users (Figs. 4 and 5)

Whenever more than one user is to be connected to the receive system, there is no way to go round extending it. As illustrated in Figs. 4 and 5, a number of options are available.

For quite some time, the option shown in Fig. 4 was the most widely used. However, the use of 2,050-MHz components (Fig. 5) enables the system size and outlay to be reduced. This is in spite of the fact that the 2,050-MHz compatible GP31AB LNCs are more expensive than GP32's (compare the two parts list). The multiswitch shown in Fig. 5 is used to select between two satellites instead of between two LNC polarizations. Syntrac-II receivers are used as in Fig. 4.

#### Two satellites — two to four users (Figs. 6 and 7)

This configuration is basically similar to the one described above. Here, too, the

total cost is reduced considerably by the use of GP31AB converters — the parts list indicates that the use of this LNC economizes on no fewer than four A/B

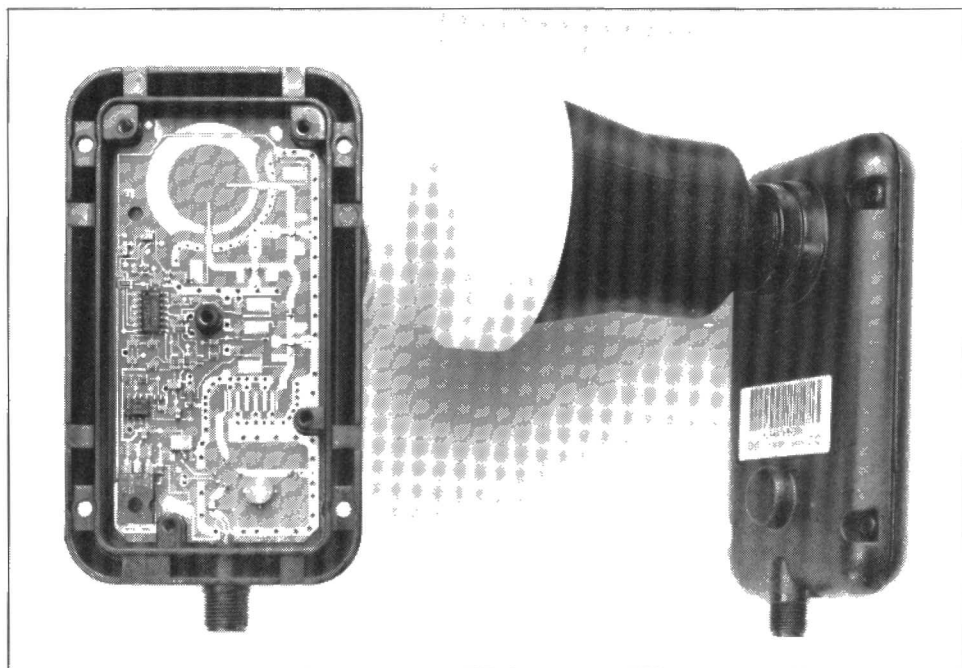


Fig. 8. A modern LNC with electrical 14/18 V H/V polarization switching (Continental Microwave).

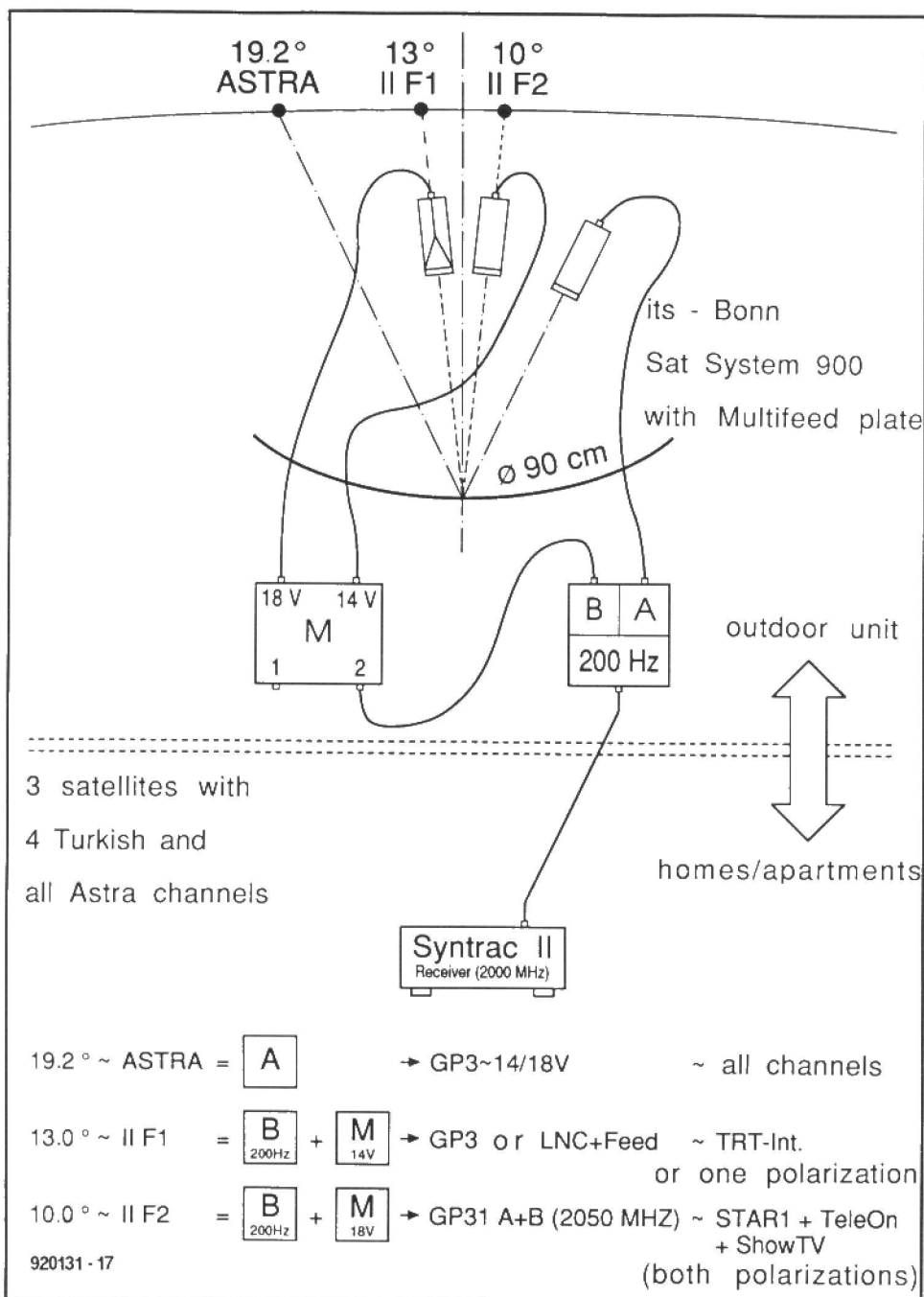


Fig. 9. Three satellites, one user.

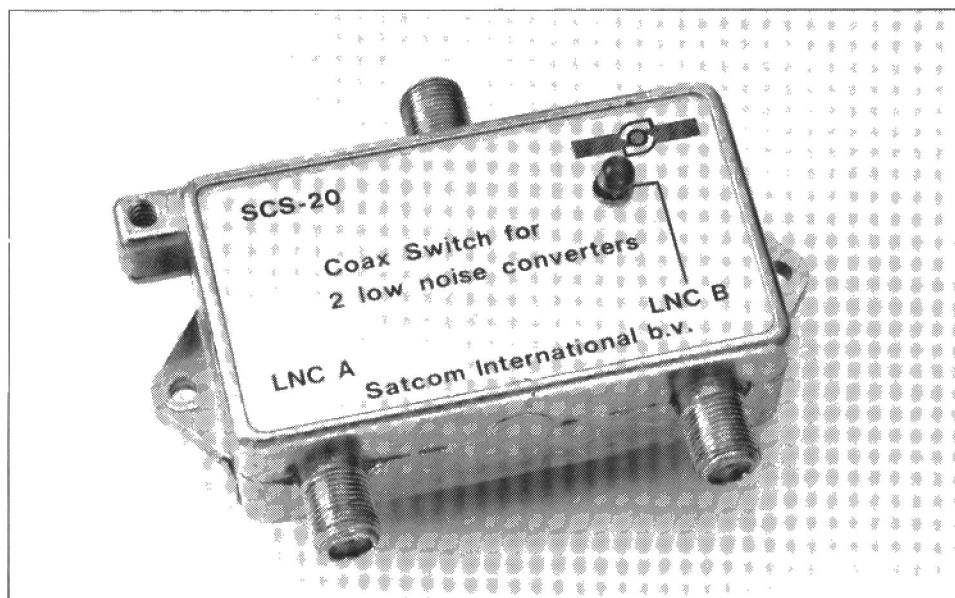


Fig. 10. The 200-Hz coax relay from SatCom International.

coax relays, and a 4-way multiswitch.

As in the above example, the 4-way multiswitch is not used for polarization switching, but for satellite selection.

### Three satellites — one user (Fig. 9) (‘single-cable solution’)

Many foreign workers, immigrants and other ex-patriates are keen on receiving more than two satellites. As an example, many Turks will be very eager to watch TRT-Int. on Eutelsat II-F1, TeleOn + Star 1 and Show-TV on Eutelsat II-F2, in addition to the Astra programmes. If the coax relay is not energized, Astra is selected via output A. Polarization switching is achieved via the 14/18 V control voltages as usual. These voltages are passed by the coax relay.

The II-F2 satellite is selected by applying the 200-Hz switchover signal to the coax relay, which switches to output B, and carries a fixed voltage of 18 V. Unfortunately, the Turkish programmes are transmitted at different polarizations. Since the 14/18 V LNC voltage is required for the selection of two of the three satellites via the multiswitch, we once again use the Type GP31AB LNC, which supplies the signals in the two polarization fields in two output (IF) frequency ranges. When the third satellite is selected, the signal flow is once again via output B of the relay, but this time with a 14 V fixed voltage on the other output of the multiswitch. Although only one polarization is available for the third satellite, this is fortunately sufficient to receive the missing Turkish as well as all other horizontally polarized programmes. If it is required, for some reason or other, to receive both polarizations, the GP31AB LNC may be used.

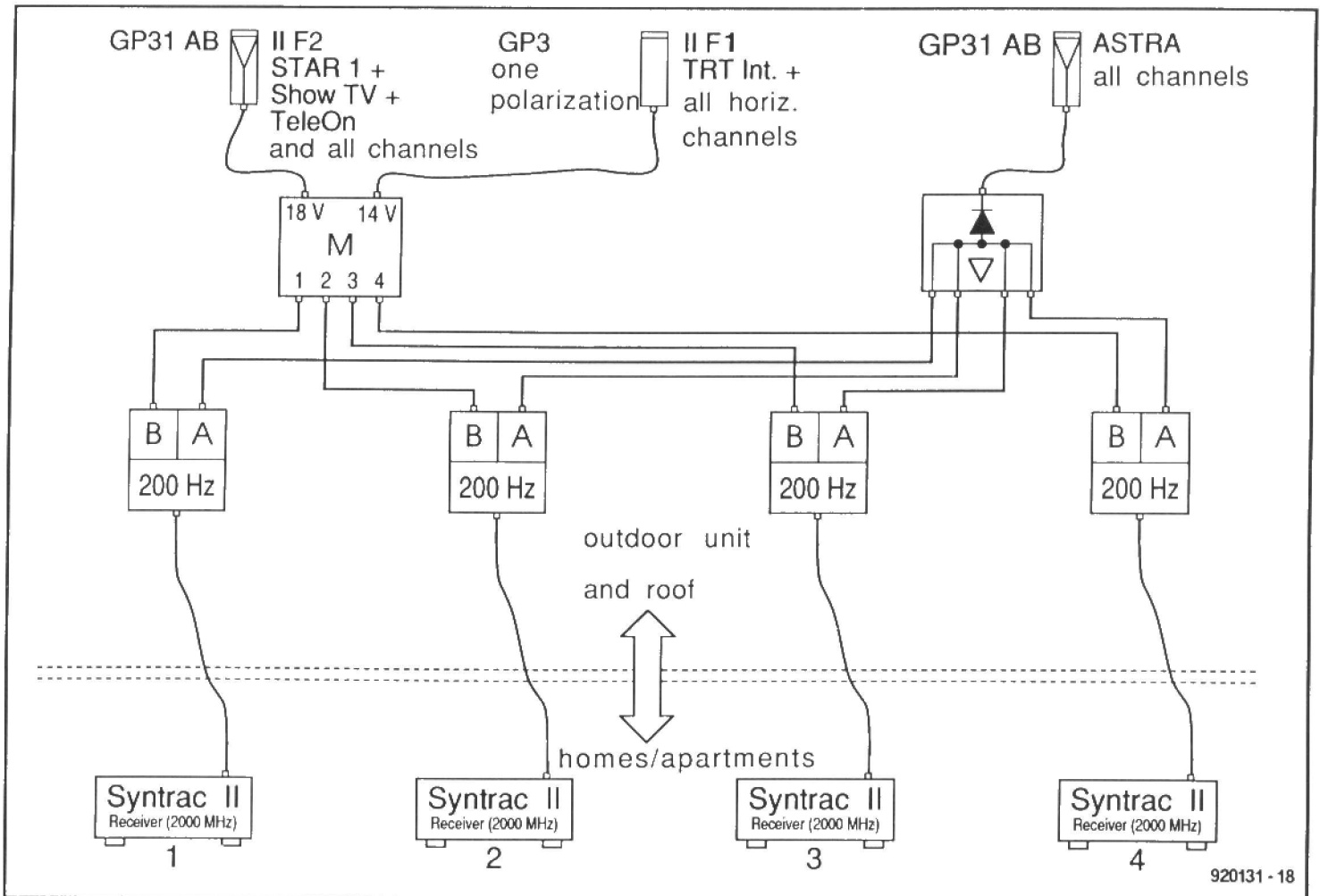
### Three satellites — two to four users (Fig. 11)

While it is possible to choose between a motor driven system and a multi-feed in the case of a single-user receive system, there is no option but to use a fixed dish whenever more than one user is to participate. It will be impossible, however, for every user to install one or more dishes on the roof, if only because of limited space, building licenses, etc. To enable every one to watch his or her favourite programmes, the configuration of Fig. 11 is suggested. Its operation is similar to that of Fig. 9, except that the Astra LNC output signals are taken to an active splitter before they arrive at the coax relays. In this multi-user system, a GP31AB is required for the reception of the two Astra polarizations.

### Final thoughts

It should be noted that 2,050-MHz technology is still fairly new, and compatible receivers and LNCs are, unfortunately, still thin on the ground. When designing





920131 - 18

Fig. 11. The most complex system: three satellites, four users.

a receive system configuration based on 2,050-MHz compatible modules it is, therefore, necessary to be very attentive to the relevant specifications, for which the manufacturers or suppliers may have to be pressed a little.

Not all receivers claimed to be 2,050-MHz compatible actually have a tuner that can reach up that far. In many cases, the gain drops to very low levels above 1,800 MHz or so, which results in noisy signals above this frequency.

When buying a 2,050-MHz LNC, be sure that the conversion gain is the same for both polarizations. Here, too, there are many products that fail miserably. It is therefore good practice to test everything on receipt of the materials, and return anything that does not meet the specifications. ■

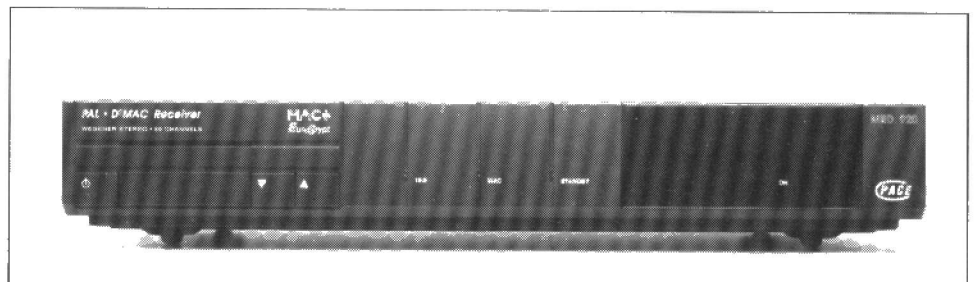


Fig. 12. PACE PAL/D2MAC receiver with two LNB inputs and a built-in Eurocrypt decoder.

### Some useful addresses

PACE Micro Technology  
Satellite receiver dept.  
Allison Road  
Bradford, W. Yorks  
Telephone: (0274) 532000  
Fax: (0274) 547124

EutelSat  
Dept. Applications nouveaux  
Mr. Christian Zippel  
Tour Maine-Montparnasse 33  
Avenue du Maine  
F-75755 Paris Cedex 15  
FRANCE

SatCom International b.v.  
Coenecoop 19

NL-2991 PG Waddinxveen  
HOLLAND  
Telephone: +31 1828 19522  
Fax: +31 1828 16242

ITS  
att. Mr. Tell  
Milchpützweg 5  
D (W) 5307 Wachtberg-Pech  
GERMANY  
Fax: +49 228 326570

Heinrich Zehnder GmbH  
Kirchstrasse 14  
D (W) Tennenbronn  
GERMANY

# WATT-HOUR METER – PART 1

Design by M. Ohsmann

Since low energy consumption of domestic appliances benefits your bank account as well as the environment (provided that their production is also economic and environment-friendly), the watt-hour meter, which can monitor the energy use of many appliances, will be of interest to many. Even if current and voltage are not sinusoidal, or out of phase with one another, the meter determines the use of energy accurately.

The watt-hour meter can measure current, voltage and energy used by refrigerators, deep-freezers, washing machines, or that provided by a solar panel, and can also monitor the charging of a battery. The available measuring ranges enable the consumption of a 300 mW bicycle lamp as well as that of a 3 kW electric hob plate to be monitored.

Primarily intended as a stand-alone unit, the meter may also be used in conjunction with a computer. This will be discussed further in Part 2.

To measure energy, three other quantities have to be known: voltage, current and time. How it is done with the watt-hour meter is shown in Fig. 1. The voltage and current delivered by a generator to a load are measured relative to time with the aid of a microcontroller, which consists of an analogue-to-digital (A-D) converter with switched inputs and a timer. The current is measured by passing it through a shunt resistor that converts it into a directly proportional voltage. The resistor is shown for clarity only; in practice it is part of the meter.

The range of input voltages is determined by a series resistor that also provides current limiting. Before the voltage and current are applied to the controller, they are amplified and rectified. Their polarity is determined by a comparator whose output is linked to a digital input of the controller. This arrangement makes it appear as if the A-D conversion were upgraded from eight to nine bits.

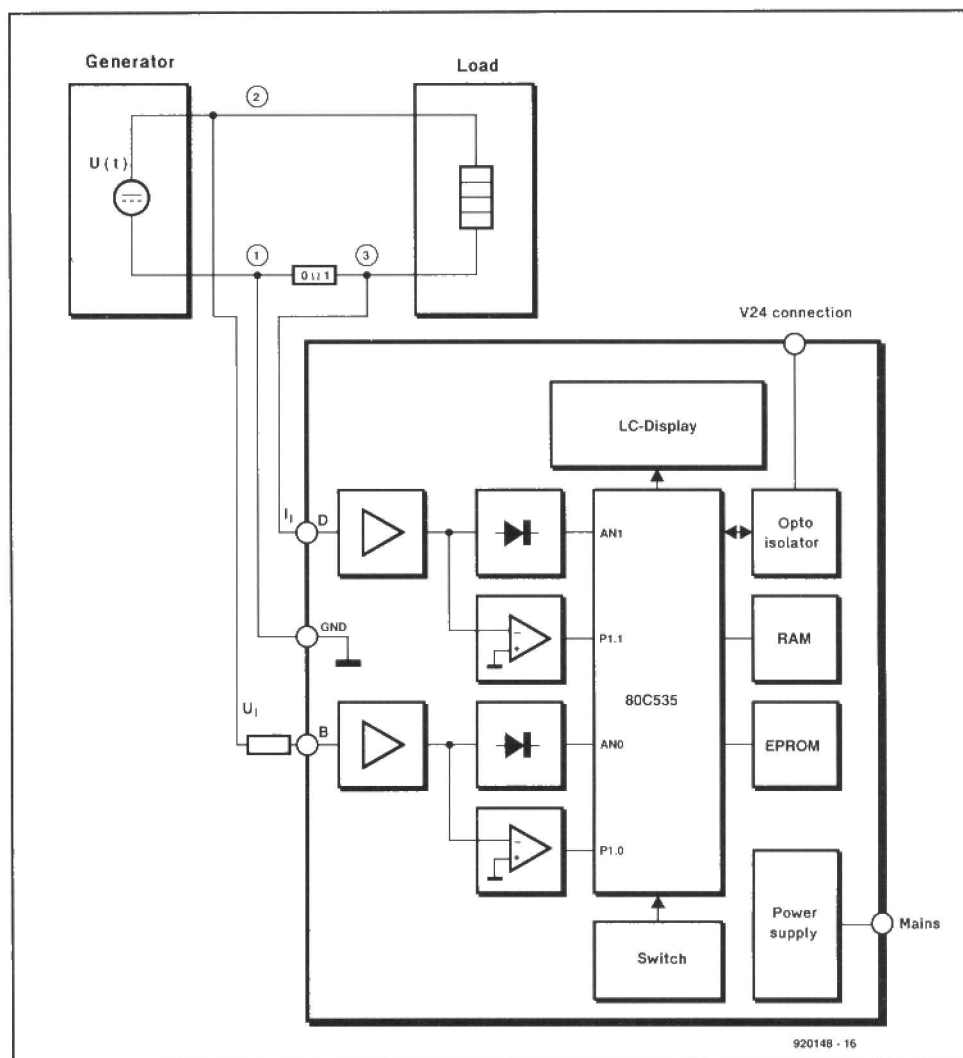


Fig. 2. Block diagram of the watt-hour meter.

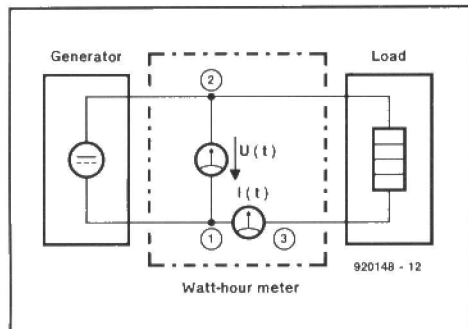


Fig. 1. The energy supplied to a load is determined by measuring the voltage across, and the current to, the load.

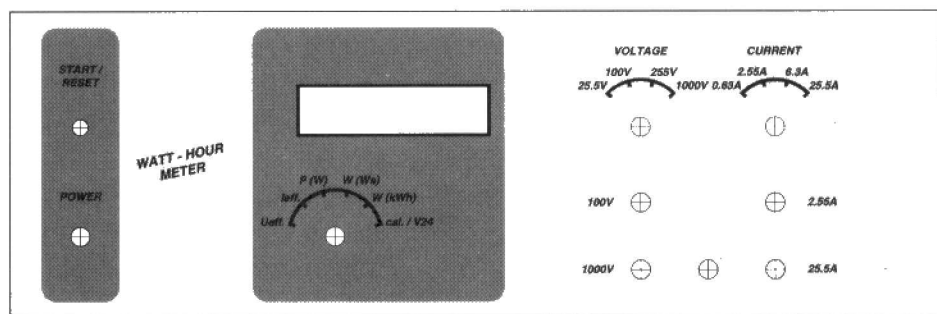


Fig. 3. A front panel foil (here scaled down to 75%) is available: see page 70.



## Circuit description

Apart from the two input stages, the circuit is almost a standard application of a controller from the MCS51 family. Note that the circuit does not show the entire meter: the series resistors at the voltage input, the shunt resistors for measuring current, and the display, are absent. The resistors will be discussed later; the display is a ready-made unit about which

nothing much needs to be said other than that  $P_1$  controls its contrast.

The series resistors form an integral part of inverting amplifier  $IC_1$ . The meter has two inputs: one for voltages of 100–1000 V and one for 0–100 V. This arrangement saves a (hard to find and expensive) switch rated at 1000 V. Four voltage (peak value!) ranges can be selected with  $S_2$ —see Fig. 2. The input voltage is adjusted with  $P_2$  and  $P_3$ .

After it has been amplified, the signal is applied to a precision rectifier based on  $IC_{3a}$  and  $IC_{3b}$ . The rectified signal is applied to the analogue input, AN0, of controller  $IC_{15}$ . The polarity of the signal, before it is rectified, is determined by comparator  $IC_{2a}$ , whose output is linked to one of the many I/O gates of  $IC_{15}$ .

The input stage for current measurements is largely identical to that for the voltage measurement, with the addition

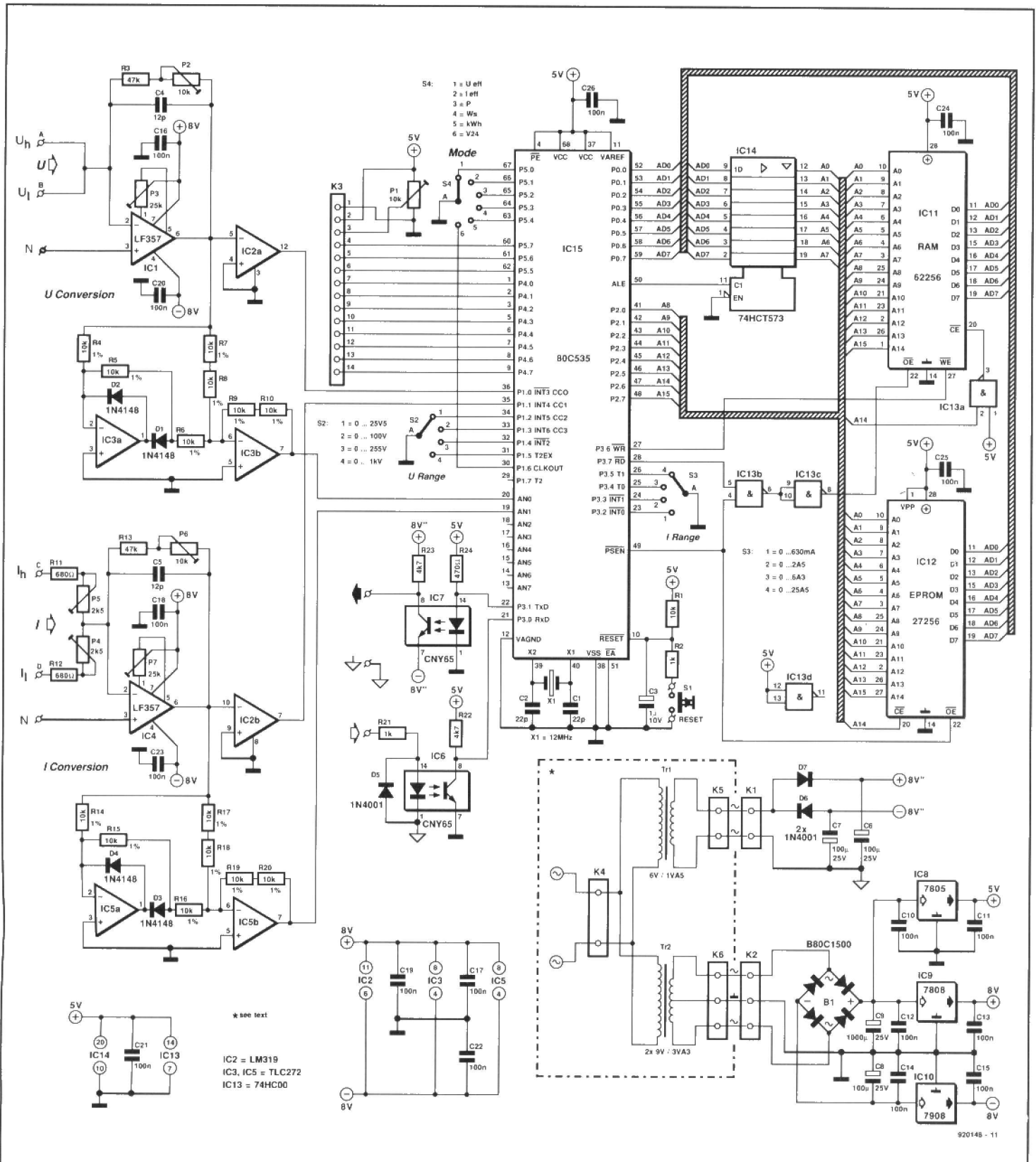


Fig. 4. Circuit diagram of the watt-hour meter.

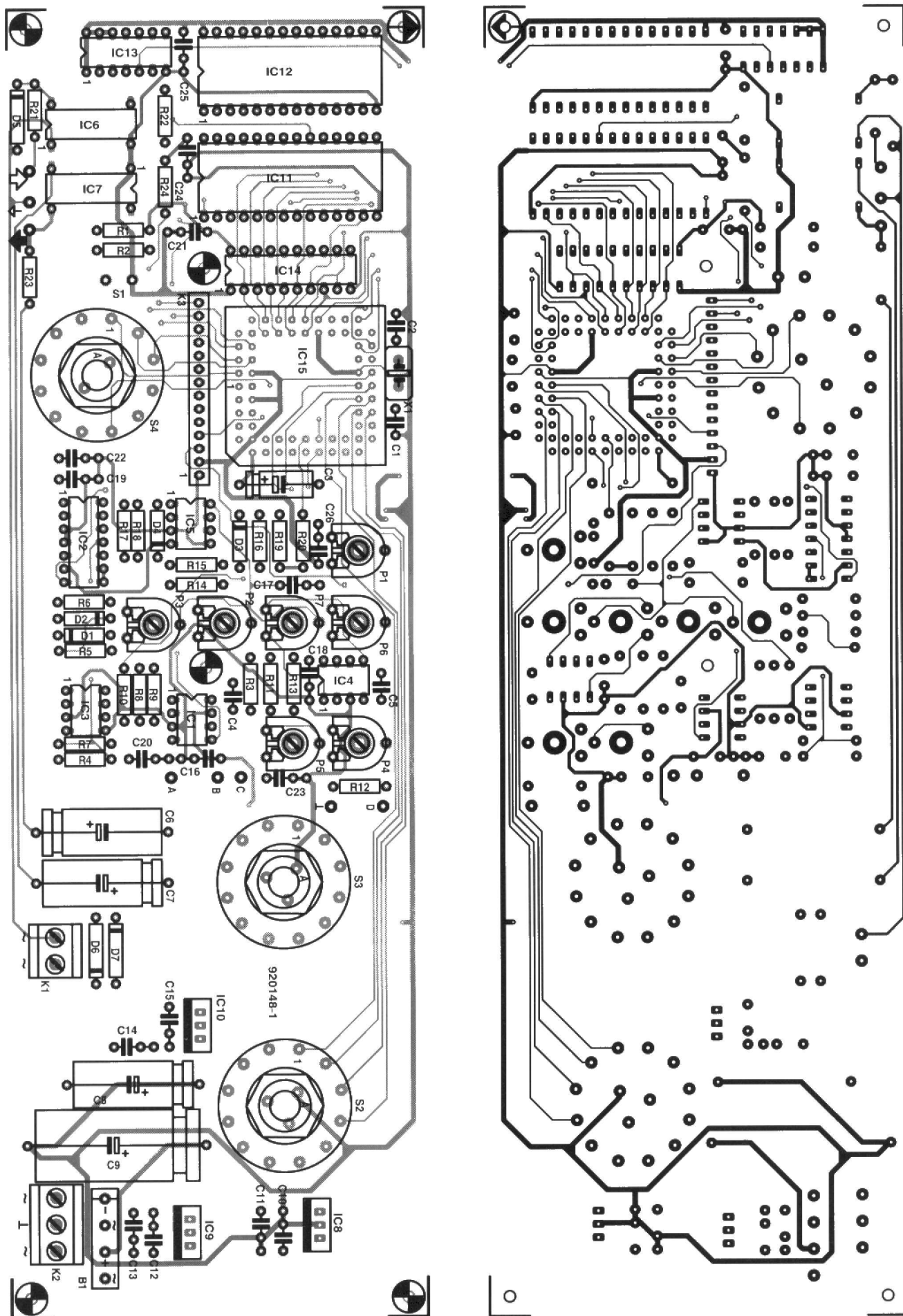
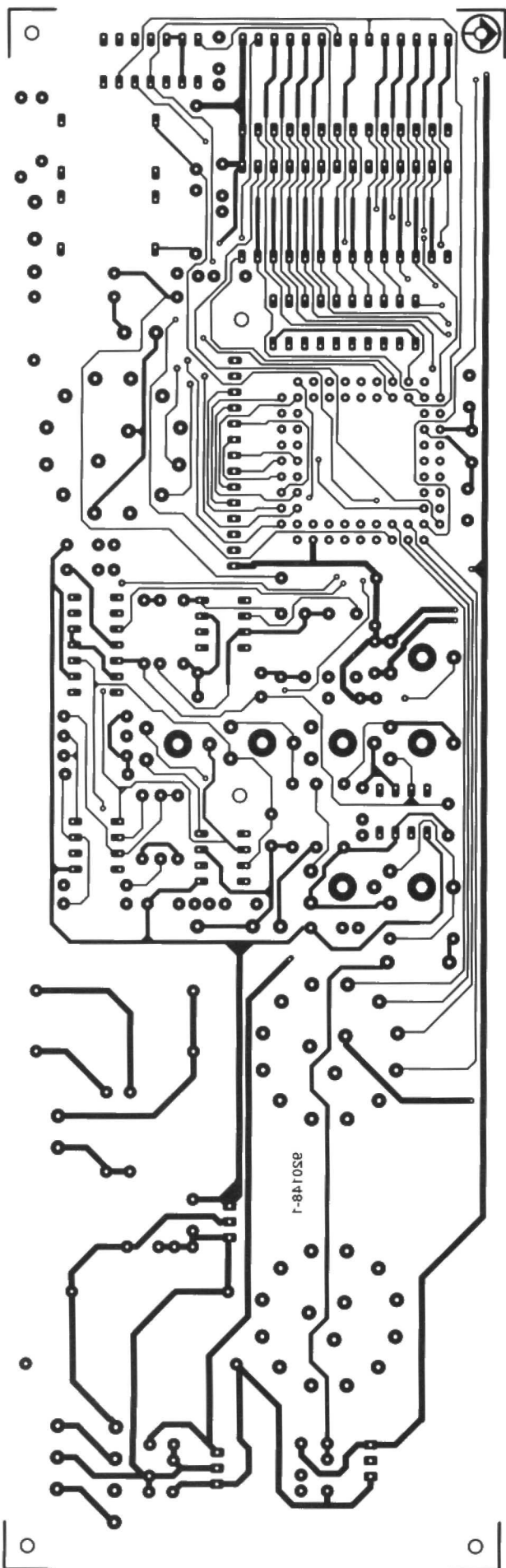


Fig. 5. Motherboard.





## PARTS LIST

### Resistors:

R1 = 10 k $\Omega$   
 R2, R21 = 1 k $\Omega$   
 R3, R13 = 47 k $\Omega$   
 R4-R10, R14-R20 = 10 k $\Omega$ , 1%  
 R11, R12 = 680  $\Omega$   
 R22, R23 = 4.7 k $\Omega$   
 R25, R26, R27 = 3.32 M $\Omega$ , 1%  
 R28, R31, R32 = 3.32 k $\Omega$ , 1%  
 R29 = 10 m $\Omega$ , 8 W  
 R30 = 100 m $\Omega$ , 1 W  
 P1, P2, P6 = 10 k $\Omega$  preset  
 P3, P7 = 25 k $\Omega$  preset  
 P4, P5 = 2.5 k $\Omega$  preset

### Capacitors:

C1, C2 = 22 pF  
 C3 = 1  $\mu$ F, 10 V  
 C4, C5 = 12 pF  
 C6-C8 = 100  $\mu$ F, 25 V  
 C9 = 1000  $\mu$ F, 25 V  
 C10-C26 = 100 nF

### Semiconductors:

D1-D4 = 1N4148  
 D5-D7 = 1N4001  
 B1 = B80C1500  
 IC1, IC4 = LF357  
 IC2 = LM319  
 IC3, IC5 = TLC272  
 IC6, IC7 = CNY65  
 IC8 = 7805  
 IC9 = 7808  
 IC10 = 7908  
 IC11 = 62256  
 IC12 = 6243 (see p. 70)  
 IC13 = 74HC00  
 IC14 = 74HC573  
 IC15 = SAB80C535

### Miscellaneous:

K1, K5 = 2-way terminal block; pitch 5 mm  
 K2, K6 = 3-way terminal block; pitch 7.5 mm  
 K3 = 14-way terminal block; pitch 5 mm  
 K4 = 2-way terminal block; pitch 7.5 mm  
 S1 = single-pole, spring-loaded switch with make contact  
 S2, S3, S4 = 1-pole, 12-way rotary switch for PCVB mounting with polythene spindle  
 Tr1 = short-circuit-proof mains transformer, secondary 6V, 1.5 A  
 Tr2 = short-circuit-proof mains transformer, secondary 9V, 3.3 A  
 X1 = 12 MHz crystal  
 LCD module Type LTN211F-0 (Philips Components)  
 5 insulated banana (or similar) sockets and plugs  
 9-way female D connector  
 1 mains entry plug  
 1 mains switch  
 1 PCB Type 920148-I\*  
 1 PCB Type 920148-II\*

\*See page 70.

of  $R_{11}/P_5$  and  $R_{12}/P_4$ . As for voltages, the meter has two inputs for currents: one for 0-2.55 A and one for 2.55-25.5 A. Again, this saves a (large and expensive) switch that can handle 25 A. Four current (peak value!) ranges can be selected with  $S_3$ —see Fig. 2.

The third rotary switch,  $S_4$ , enables selecting the quantity to be measured: voltage,  $U_{\text{eff}}$ ; current,  $I_{\text{eff}}$ ; power (in watts); energy or work done in watt-seconds (W-s); and energy or work done in kilowatt-hours (kWh).

Memory of the meter is contained in a 32-kbyte EPROM, IC<sub>12</sub>, and a 32-kbyte RAM, IC<sub>11</sub>. Both are connected to address lines A14 and A15 in the standard manner. In Fig. 4, A14 and A15 have been interchanged, so that the memory division is more or less the same as that of the 8032/8052 compuboard used in last year's assembler course.

The serial input and output of the controller are provided with optoisolators that electrically separate the meter and anything connected to it. This means that a supply voltage must be provided for IC<sub>7</sub> that is isolated from the rest of the meter. This isolation is provided by Tr<sub>1</sub>. Since this transformer is lightly loaded, the secondary voltage may be a few volts higher than stated, but that gives no problems with an RS232 connection.

The isolation provided by transformer Tr<sub>2</sub> is also of real benefit. For instance, without it, the meter could not be connected to the mains supply: one of its primary objectives. Do not confuse the 8 V outputs of the main supply with the 8V supply for IC<sub>7</sub>.

## Construction

Since the meter is often connected to the mains, not only via the two transformers, but also via the measuring inputs, the utmost care must be taken in the construction of the meter.

The mother board is shown Fig. 5 and the transformer board in Fig. 8. The mother board may be fitted to the front panel, but it may also be mounted on a subframe. In any case, the assembly MUST be carried out with man-made fibre bolts, nuts, washers and spacers. Metal ones must NOT be used in any circumstances, since several fixing holes are not sufficiently far away from voltage-carrying parts on the board.

The potentiometers may be mounted on the component side or on the track side of the board, but reset switch  $S_1$  always on the track side. Unless this component meets the same insulation requirements as a mains on-off switch, it must be impossible to access it without opening the enclosure.

The rotary switches MUST have a man-made fibre spindle.

The display poses a safety problem, because, as usual, this should be mounted as close to the front panel as possible.

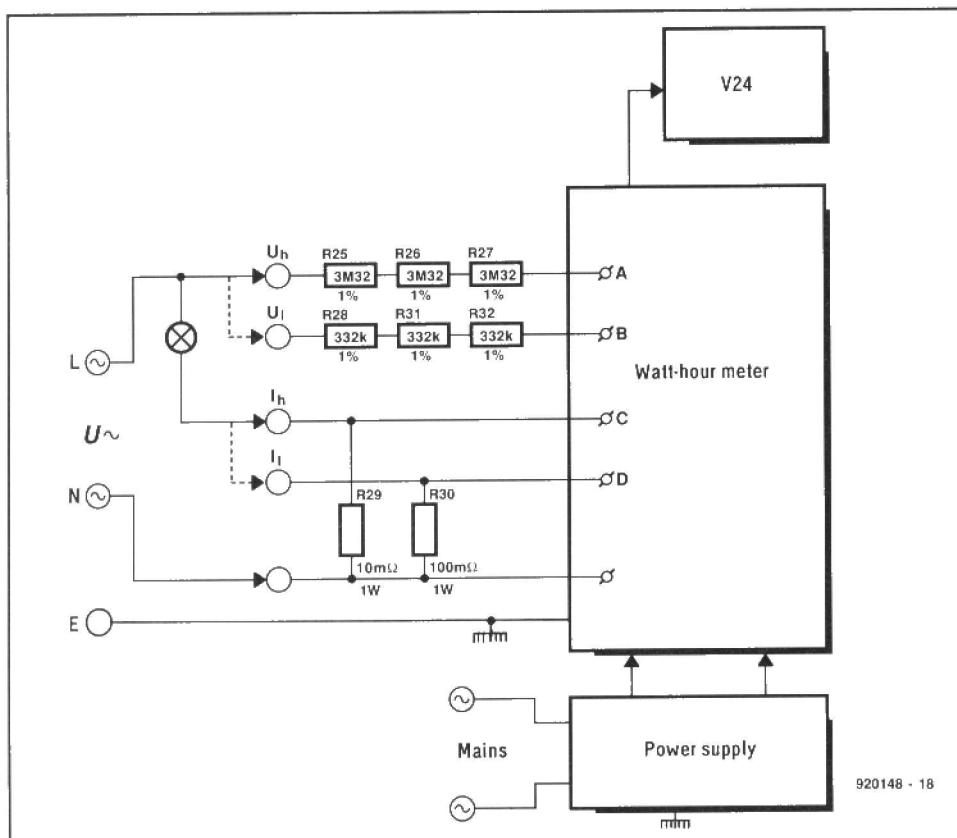


Fig. 6. A number of resistors must be soldered between the mother board and the input sockets. The remainder of the wiring is self-evident.

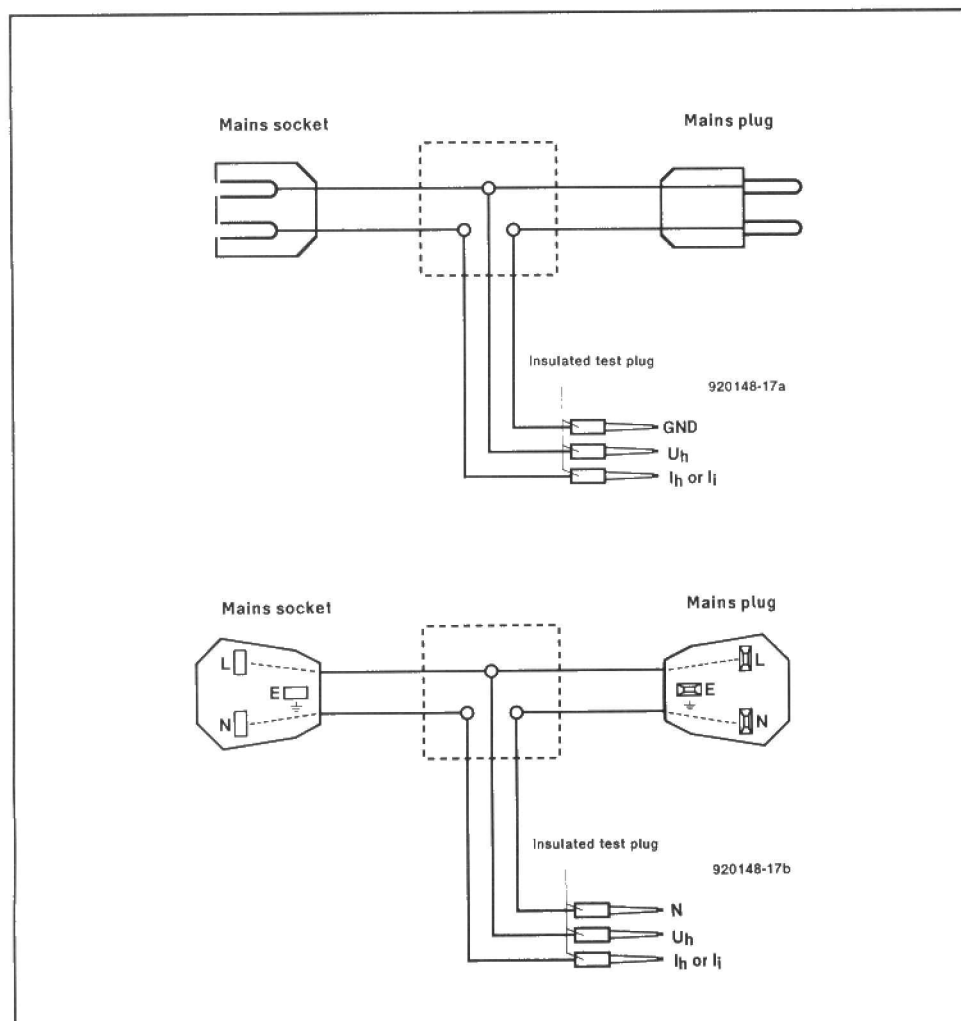


Fig. 7. The input sockets are types that match insulated banana (or similar) plugs. The top diagram refers to the use of European or American mains plugs and sockets; the bottom one to British three-pin types.

This cannot be done, however, in this case since it would not meet insulation requirements. The solution lies in glueing a sheet of perspex to the front panel that is in all directions 6 mm larger than the display.

The display is mounted on to the mother board with the aid of 2 bolts, nuts and spacers. After that, make the 14 connections to  $K_3$  with circuit wire. A number of resistors must be connected between the input sockets and the mother board as shown in Fig. 6. The mains earth must be connected to the metal parts of the enclosure but NOT to the G(rou)ND of the circuit. A fuse is not needed if the transformers specified in the parts list are used, because these are short-circuit-

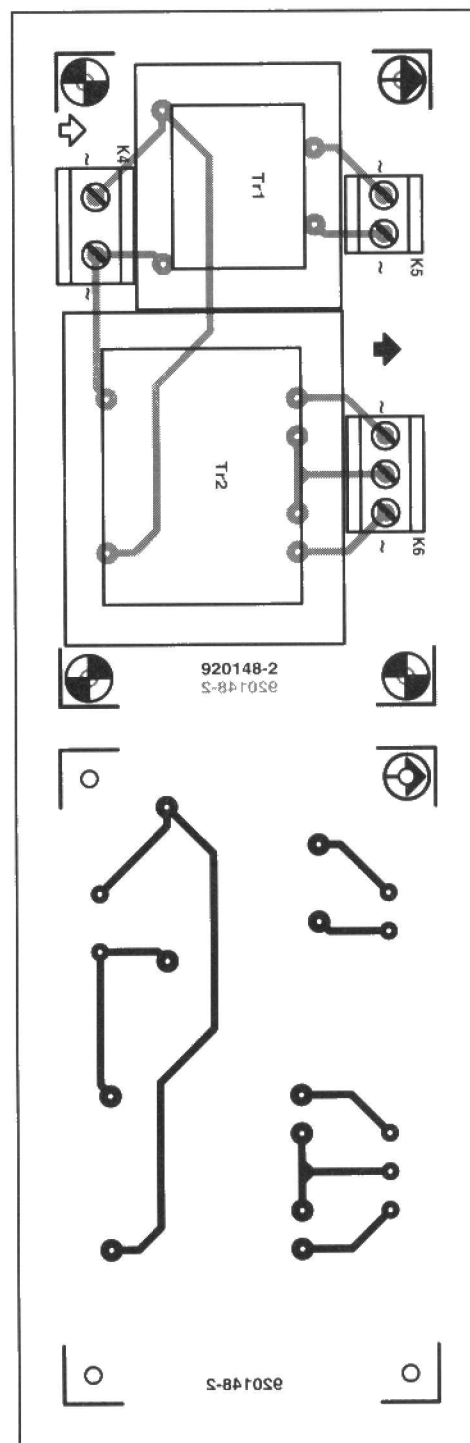


Fig. 8. Transformer board.



**SPECIFICATION****Measuring ranges**

Voltage (true r.m.s.) 25.5 V; 100 V; 255 V; 1000 V (max)  
( $U_{peak} = 1000$  V)

Current (true r.m.s.) 0.63 A; 2.55 A; 6.3 A; 25.5 A (max)  
( $I_{peak} = 25.5$  A)

Active power in Watt\*

Energy in Watt-seconds or kilo-Watt-hours\*

Frequency range DC–1 kHz

Sampling frequency 5 kHz

Time indication (energy 0–10 000 hours (416 days)  
measuring period)

Alphanumeric display 2 lines of 16 characters each

Can be read and controlled via an electrically isolated RS232  
interface

Can be calibrated with a simple digital multimeter

Freely programmable control computer via integral monitor-  
ing program Type EMON52

\*Range depends on current and voltage settings

proof. Before soldering resistors  $R_{25}$ – $R_{28}$ ,  $R_{31}$  and  $R_{32}$  between the board and input sockets, insert them into a length of insulating sleeve. Solder shunt resistors  $R_{29}$  and  $R_{30}$  direct to the input sockets. It may be necessary (owing to its non-availability in your locality) to make  $R_{29}$  from a 1.8 mm thick (2.5 mm<sup>2</sup> cross-sectional area) piece of wire 145 cm (4 ft 9 in) long. The connections between current input and common sockets and the board must be twisted to prevent them picking up hum. The sockets on the meter and the corresponding test plugs—see Fig. 7—MUST be insulated banana (or similar) types.

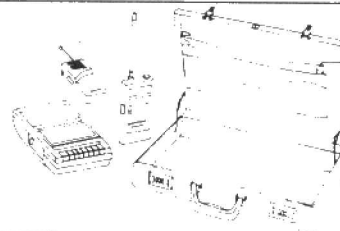
**Initial tests**

When everything has been built and checked, set all potentiometers to the centre of their travel and  $S_4$  to position cal/V24. Only then, switch on the mains. Leave the inputs open. Adjust  $P_1$  for good legibility of the text on the display. It should read 'EMON52 MODE' to indicate that the controller works correctly. If that text is not there, check the supply voltages to the various stages of the circuit. If they are all right, check whether the ALE signal is present. If that also is all right, carefully check the boards in detail, paying particular attention to possibly overlooked solder connections or tiny flecks of solder between tracks. ■

Next month's instalment will deal with the calibration and operation of the watt-hour meter.

**SURVEILLANCE****A SMALL SAMPLE OF OUR RANGE**

	KIT	MODULE	PROF. FINISHED
<b>ROOM TRANSMITTER RT1</b> An extremely sensitive miniature transmitter with long battery life. Dimensions: 20 x 20mm	9.95	13.75	19.00
<b>MAINS TRANSMITTER MT4</b> Can be connected inside any equipment that is mains powered. Dimensions: 35 x 20mm	19.75	31.50	45.00
<b>TELEPHONE TRANSMITTER TTS</b> Small enough to conceal within a telephone. Will transmit both sides of a conversation (series connection) Dimensions: 10 x 20mm	12.75	17.50	25.00
<b>TELEPHONE TRANSMITTER TTP</b> Similar to TTS will monitor all telephones on the line (parallel connection) Dimensions: 15 x 27mm	21.95	31.50	45.00
<b>TELEPHONE SOCKET TRANSMITTER TSTS</b> Replace your telephone socket with this one within which a transmitter has been concealed.	14.74	-----	29.00
<b>ROOM AND TELEPHONE TRANSMITTER RTT</b> Operates as a room transmitter, then switches to telephone transmitter mode during telephone calls. Dimensions: 30 x 25mm	31.50	45.50	65.00
<b>AUTOMATIC TELEPHONE RECORDER SWITCH TRS2</b> Record telephone conversations with this interface unit and your own tape recorder. Dimensions: 36 x 50mm	16.80	25.90	39.00
<b>AUTOMATIC TELEPHONE RECORDER ATR1</b> Adapt the tape recorder included to record telephone calls automatically.	34.95	-----	59.00
<b>TELEPHONE TAP ALERT TTA1</b> Visual warning of any invasions of privacy on your telephone line. Dimensions: 38 x 52mm	21.95	31.50	45.00
<b>RF DETECTOR RFD1</b> Highly sensitive hand-held detector. Range between 10Mhz and 600Mhz. Silent operation. Dimensions: 70 x 50mm	42.75	69.00	95.00
<b>CAMERA DETECTOR CDB</b> Detects hidden video cameras (even miniature CCD models). Dimensions: 63 x 38mm	69.00	89.00	125.00
<b>RECORDING BRIEFCASE RBC1</b> Build your own discrete recording briefcase.	-----	-----	145.00
<b>SHOTGUN MICROPHONE AMPLIFIER SMA</b> Ideal for surveillance. The amplifier will pick up sounds from a long distance.	24.95	36.00	45.00
<b>SIGNALLING TRANSMITTER SIGT</b> Sends a continual audio pulse. Can be integrated into alarm, tracking or warning systems. Dimensions: 20 x 50mm	21.95	34.89	45.00
<b>REMOTE SWITCHING SYSTEM RSS</b> Transmitter/receiver set. Applications include car security and remote control of household appliances. Dimensions: Single channel transmitter, 45 x 35 x 12mm; Receiver, 50 x 60 x 25mm; Double channel transmitter, 56 x 35 x 10mm; Receiver, 50 x 60 x 25mm		Single channel Double channel	39.00 49.00
<b>TELEPHONE AMPLIFIER TA5</b> Connected directly to the telephone, this unit will amplify both sides of a telephone call. Dimensions: 25 x 52mm	10.95	16.95	19.95
<b>PROFESSIONAL SOUND TO LIGHT UNIT SK72</b> Custom built for disco or home use. Audio signal divided into bass, mid and treble bands, with internal microphone and spotlight option. Dimensions 210 x 45mm	21.95	32.49	44.95
<b>1.5-12V POWER SUPPLY PSU</b> Versatile low cost unit with variable or fixed voltage control (specify on ordering). Regulation better than 1%. Dimensions: 60 x 43mm	9.95	15.95	-----
<b>MICRO LIVE WIRE DETECTOR LWD</b> Without actual connection will warn of the presence of AC mains live. Dimensions: 40 x 25mm	9.95	16.95	-----
<b>MICRO METAL DETECTOR MMD</b> Detect the presence of ferrous and various non-ferrous metals. Useful for all those DIY jobs. Dimensions: 40 x 25mm	9.95	16.95	-----



Please add £2.00 P & P to all orders and 17.5% VAT on all U.K. orders.

For full catalogue please send two 1st class stamps or 2 IRC'S

172 Caledonian Road

Dept EL



CANAL

London N1 0SG

BRIDGE AUDIO

071-837 4423



# FIGURING IT OUT

## PART 2 – CAPACITOR MATHS

By Owen Bishop

This series is intended to help you with the quantitative aspects of electronic design: predicting currents, voltage, waveforms, and other aspects of the behaviour of circuits.

Our aim is to provide more than just a collection of rule-of-thumb formulas.

We will explain the underlying electronic theory and, whenever appropriate, render some insights into the mathematics involved.

### Correction

At the end of last month's instalment it was stated erroneously that this month's issue would contain more applications of KCL and KVL; these will be discussed, however, in our March issue.

The fundamental relationship for capacitors is the equation that defines the unit of capacitance,  $C$ , which is the farad:

$$C = Q/U.$$

The capacitance in farad is the electric charge,  $Q$ , expressed in coulombs per volt potential difference,  $U$ , between the plates of the capacitor. From this, we obtain the equation for the charge on a capacitor:

$$Q = CU. \quad [\text{Eq. 14}]$$

If a capacitor begins by being uncharged, and a constant current  $I$  passes to one plate for a time  $t$ , the amount of charge on the capacitor at the end of that period is

$$Q = It. \quad [\text{Eq. 15}]$$

This equation defines the coulomb. Combining Eq. 14 and Eq. 15 gives:

$$U = It/C. \quad [\text{Eq. 16}]$$

Given the capacitance, the constant current and the length of time for which the current has flowed, we can calculate the potential difference between the plates. For example, if a current of 2 A flows for 0.5 s into a capacitance of 0.01 F (arad), the pd between its plates is:

$$U = 2 \times 0.5 / 0.01 = 100 \text{ (V)}.$$

### Answers to Test Yourself – Part 1

- 1 a 1.875  $\Omega$ ; b 8.2  $\Omega$ ; c 3  $\Omega$ ; d 4  $\Omega$   
 3  $I_1 = 1.5 \text{ A}$ ;  $I_2 = 0.5 \text{ A}$ ; 11 V across AB; 0.5 V across 1  $\Omega$ ; 3 V across 2  $\Omega$ ; 8 V across 4  $\Omega$ ; 2.5 V across 5  $\Omega$

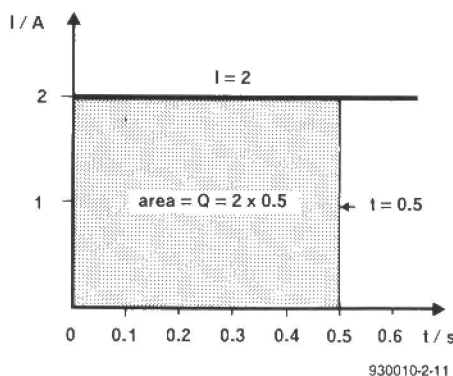


Fig. 15. Capacitor being charged by a constant current.

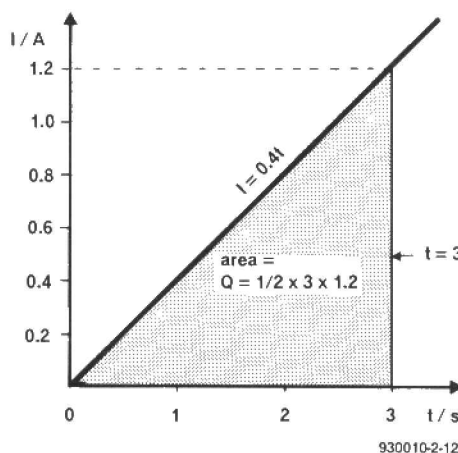


Fig. 16. Capacitor being charged by a ramping current.

In Eq. 16, the term  $It$  is the product of the current and the length of time the current has flowed. In Fig. 15, which plots

the current  $I$  in A at each instant of time  $t$  in s(econds), this product is represented by the shaded area beneath the graph.

This area is the product of the height (current) and width (time) of the line. The amount of charge on the capacitor at any given instant equals the area beneath the line.

There is no difficulty in performing such calculations when the current is constant. There is certainly no need to draw a graph. Complications arise, however, when the current is **not** constant. Suppose that the current is zero to begin with, but increases steadily at a rate given by the equation:

$$I = at,$$

where  $a$  is a constant expressing the rate of increase of current in amperes per second,  $\text{A s}^{-1}$ . Figure 16 shows the situation when  $a = 0.4 \text{ A s}^{-1}$ . The graph shows that  $I$  attains a value of 1.2 A after a period of 3 s. Calculating the charge on the capacitor after 3 s is simply a matter of evaluating the area beneath the graph. We use the formula

$$\text{area} = \frac{1}{2} \text{base} \times \text{height}$$

to obtain the answer which is 1.8 C(oulomb). If the capacitance is 0.01 F as before, the pd between the plates is  $1.8/0.01 = 180 \text{ V}$ .

In the calculation just completed, we were able to make use of elementary geometry to calculate the area and hence the charge and pd. This method is not practicable if the current is varying in some more complicated way. Suppose the current is varying in an entirely random manner as in Fig. 17. The area has an irregular upper boundary and there is no simple geometrical way of calculating it exactly. The best we can do is to record the current at

very short intervals of time, short enough for the current not to vary significantly during each interval. This may be done by sampling the current at intervals of, say, 0.1 s with the aid of a microcomputer. The result is a series of narrow strips as in Fig. 18. We calculate the area of each strip and sum the areas to obtain the total charge. This method has an inherent error in that the upper boundary of each strip is horizontal, whereas with a continuously varying current it is sloping. The area beneath the curve is not quite the same as the total area of the strips. The error is reduced if we make the time interval smaller. If we could make the strips infinitely narrow, the error would disappear.

## Mathematical solution

The technique of sampling the current at very short time intervals has practical limitations, but fortunately the integral calculus comes to our aid. The term **integration** means 'putting together to make a whole', and the technique allows us to calculate directly the area beneath any curve that can be mathematically defined. It cannot, of course, help with irregular curves such as in Fig. 17, but any curve that can be written as a function is amenable to such treatment.

When we refer to 'a function' in this context, we mean that the way in which the current varies with time can be expressed in an equation. We have already met two such functions. In Fig. 15 the function is

$$I=2.$$

Here  $I$  is a constant; its value is independent of time and the variable  $t$  does not enter into the equation.

In Fig. 16, the function is

$$I=0.4t.$$

As already stated, we can solve problems involving such elementary functions by drawing (or imagining) the graph and using simple geometry. But more complex functions such as

$$I=2t^2-3t+6$$

and

$$I=2\sin(4+3t)$$

require the integration technique.

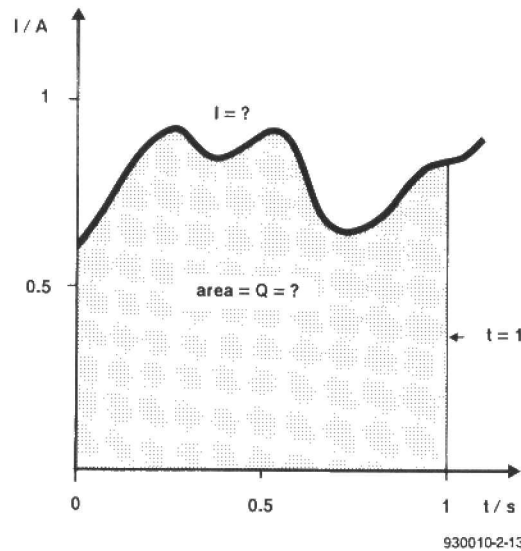


Fig. 17. Charging a capacitor with an irregular current.

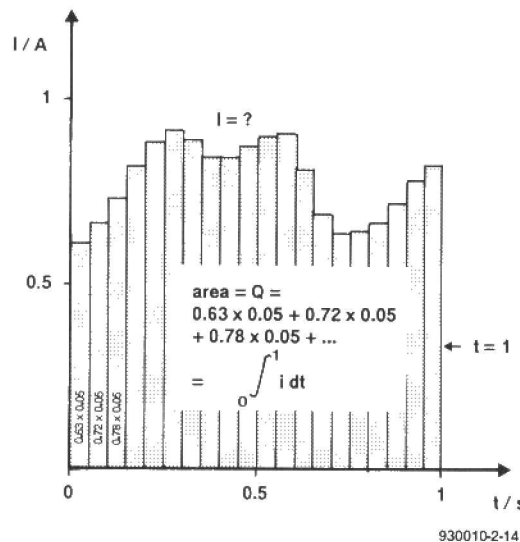


Fig. 18. Finding the charge by integration.

Standard integrals (a and b are constants)	
Function of $I$	$\int I dt$
$t^n$	$\frac{t^{n+1}}{n+1} \quad (n \neq -1)$
	$1nt \quad (n = -1)$
$e^{at}$	$\frac{e^{at}}{a}$
$\sin(at+b)$	$-\frac{1}{a} \cos(at+b)$
$\cos(at+b)$	$\frac{1}{a} \sin(at+b)$

Table 1. Some standard integrals expressed in terms of  $I$  and  $t$ .

## Integration

There is no space here to consider the theoretical basis of integration. Instead, we shall state some of the more important results and show how to use them in solving practical problems. The most useful of the results are referred to as the **standard integrals**. A few of these are listed in Table 1. Rather than expressing them in terms of variables  $x$  and  $y$ , as is usual in maths texts, we have expressed them in terms of  $I$  and  $t$  so that they may be directly applied to problems involving capacitors.

Before we go on to use the technique, there is the matter of the symbols that we use. The idea of integration is that we are summing the areas of an infinitely large number of narrow strips of infinitely small width. The integral expression refers to this in symbolic form

charge  $Q$  = area under curve =

$$\int_{t_1}^{t_2} I dt$$

The  $\int$ , or 'long s', is short for 'summation'. Following this comes a description of what we are to sum: the product of  $I$  (the length of the strip) and  $dt$  (the width of the strip). The 'd' is not a variable: it means 'infinitely small increment', so the term ' $dt$ ' means 'an infinitely small increment of time'. The  $t_1$  and  $t_2$  indicate the period of time over which summation is to be done: the period starting at  $t_1$  and ending at  $t_2$ . When solving a problem, we replace  $I$  in the expression above by the function of  $t$  which defines how  $I$  varies in time.

We will use integration to solve the problem of Fig. 16 in which the function is  $I=0.4t$ :

$Q$  = area under the curve =

$$\int 0.4t dt.$$

According to the rules of integration, a constant coefficient of  $t$  can be brought in front of the integral sign. This makes sense because any multiplier  $k$  simply makes the strips  $k$  times longer and the area  $k$  times greater. Note that we have not included  $t_1$  and  $t_2$  at this stage, as we shall first obtain an expression that applies to **any** length of time. The integral to be evaluated now is

$$Q=0.4 \int t dt.$$



Now look at Table 1. The entry which helps with this example is  $t^n$ , where  $n=1$ . Since  $n+1=2$ , the integral is

$$t^2/2.$$

Substituting this in the equation

$$Q=0.4(t^2/2)=0.2t^2.$$

This expression tells us the amount of charge at any given **instant**,  $t$ . This is the **indefinite integral**. In the original problem we wanted to know how much charge accumulated during the given **period**, defined as  $t_1=0$  to  $t_2=3$ . We find this by calculating the **definite integral** as follows

$$Q = 0.4 \int_0^3 t \, dt = 0.4(t^2/2)_0^3$$

Here we have written the beginning and end of the time period beside the integral sign. The result of integration is written in brackets with the beginning and end times written after the last bracket. The amount accumulating during the period  $t_1$  to  $t_2$  is the amount present at  $t_2$  minus the amount present at  $t_1$ , so we can say:

$$Q = 0.4(t^2/2)_0^3 = 0.4[3^2/2 - (0^2/2)] \\ = 0.4[9/2 - 0] = 0.4 \times 4.5 = 1.8 \text{ C.}$$

This is the same result as we obtained more simply by geometry but serves to demonstrate that the integration method gives the correct result. Before we use integration to solve problems more worthy of its capabilities, there is one point to be considered.

## Initial charge

The integral tells us how much charge has accumulated on the capacitor. But there is nothing in the equation to take account of any charge that might exist on the capacitor before the current began to flow. If the capacitor had a charge of 2C on its plates at  $t_1=0$ , this would not affect the rate at which charge accumulates subsequently. At  $t_2=3$ , the total charge would be  $2+1.8=3.8 \text{ C}$ .

When calculating the **indefinite** integral, we should allow for any possible charge by including it in the equation. In the example above, the modified equation is:

$$Q = 0.4 \int t \, dt + c,$$

where  $c$  is the initial charge, if any. In maths,  $c$  is referred to as the **constant of integration**. In the example,  $c=0$ , for this was stated when the problem was set out. Being negative implies that the initial charge is of opposite polarity and that the current flowing into the capacitor will be acting to neutralize it and possibly recharge it in the opposite direction.

Unless some statement is made about the initial charge, or we are told the total charge at a given instant in time, we cannot take account of initial charge in the calculation—we only know the amount that accumulates during the given period. Often, the initial charge is known to be zero, so it may be ignored. In other cases, additional information is given, as in this example.

Current is flowing into a capacitor at a rate given by  $I=2t+1$ . The charge on the capacitor at time 2 s is 10 C. What is the charge at time 5 s? The total charge is given by:

$$Q = \int (2t+1) \, dt + c.$$

We integrate each term of the expression individually, using the standard integrals:

$$Q = 2 \int t \, dt + \int 1 \, dt + c \\ = 2(t^2/2) + t + c.$$

Note that when integrating the constant '1', we consider it to be  $1t^0$ , so that we take  $n$  to be zero. The question states that  $Q=10$  when  $t=2$ . Substituting these values:

$$10 = (2 \times 4)/2 + 2 + c = 6 + c,$$

$$\therefore c = 4.$$

The initial charge, or constant of integration, is 4. Now we can evaluate the charge after 5 s:

$$Q = (2 \times 5^2)/2 + 5 + 4 = 25 + 9 = 34 \text{ C.}$$

The constant of integration is ignored when we are calculating **definite** integrals, as the integrals at time  $t_1$  and at time

$t_2$  both have  $c$  added to them. The constants disappear when one is subtracted from the other. Putting it in terms of charge, the amount of charge accumulating during a given period is not affected by whatever charge happened to be on the capacitor already.

If the current function is more complex than those in Table 1, special integrating techniques are required, which will be found in advanced maths texts. However, the table covers most of the situations commonly met in electronic circuits. In particular, the sine function is characteristic of audio signals and is, therefore, a feature of many types of circuit, including amplifiers, oscillators and filters. We deal with this in the next section.

## Sinusoidal currents

It often happens that a capacitor is being charged by a current that is varied according to a sine function. For example:

$$I = 2 \sin 3t.$$

How much charge accumulates during 0.1 s? Integrating according to the formula in Table 1:

$$Q = \int_0^{0.1} 2 \sin 3t \, dt \\ = 2 \left[ \frac{-\cos 3t}{3} \right]_0^{0.1} \\ = 2 \left\{ \left[ \frac{-\cos 0.3}{3} \right] - \left[ \frac{-\cos 0}{3} \right] \right\} \\ = 2 \{ [-0.318] - [-0.333] \} \\ = 0.03 \text{ C}$$

When evaluating the integrals of trigonometric functions, we always work in radians, not degrees, since the standard integrals are derived on that basis.

Given the same charging current, what is the charge that accumulates in 1 s? Substituting  $t_2=1$ :

$$Q = 2 \{ [-\cos 3/3] - [-0.333] \} \\ = 2 \{ 0.330 + 0.333 \} \\ = 1.326 \text{ C.}$$

Now find the charge after 2.094 s:

$$Q = 2 \{ [-\cos 6.282/3] - [-0.333] \} \\ = 2 \{ [-0.333] - [-0.333] \} \\ = 0 \text{ C.}$$

What has happened to the charge? Figure 19 shows that the

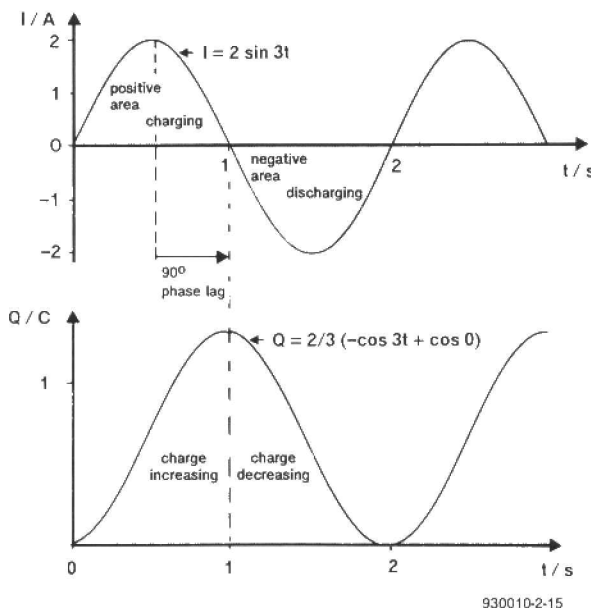


Fig. 19. At the top a sinusoidal charging current and below the resulting charge on a capacitor.

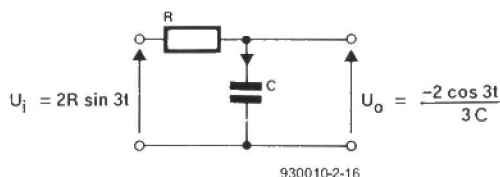


Fig. 20. Resistor-capacitor network.



# DESIGN IDEAS

The contents of this article are based solely on information supplied by the author, and do not imply practical experience by *Elektor Electronics*.

## RF ATTENUATORS

### INCLUDING SOME YOU BUILD YOURSELF

An attenuator is a circuit that reduces signal level, i.e., has an output signal level that is lower than the input signal level. In this respect, it is the opposite of an amplifier. Precision attenuators are frequently used in electronics to reduce signals a specified amount, usually expressed in decibels (dB), for some purpose such as measurement or stabilization.

By Joseph J. Carr

**A**N attenuator pad will provide the rated attenuation in dB only when the input and output impedances are terminated in a like impedance. For audio systems, it is common to use 600  $\Omega$  as the standard system impedance; in radio (and most RF) systems the impedance is 50  $\Omega$ ; in television systems it is 75  $\Omega$ .

When working with attenuators it is the custom to use decibel notation. There is often some confusion on this point because a lot of people simply misunderstand the concept of decibels.

### Decibel notation

The decibel measurement originated with the telephone industry, and was named after telephone inventor Alexander Graham Bell. The original unit was the bel. The prefix deci means 1/10, so the decibel is one-tenth of a bel. The bel is too large for most common applications, so it is rarely if ever used. Thus, we will concentrate only on the more familiar decibel (dB).

The decibel is nothing more than a

means of expressing a ratio between two signal levels, for example the 'output-over-input' ratio of an amplifier. Because the decibel is a ratio, it is also dimensionless — despite the fact that 'dB' looks peculiarly like a dimension. Consider the voltage amplifier as an example of dimensionless gain; its gain is expressed as the output voltage over the input voltage ( $U_o / U_{in}$ ), so the 'volts' in the numerator are cancelled by the 'volts' in the denominator.

In order to analyze systems using simple addition and subtraction, rather than multiplication and division, a little math trick is used on the ratio. We take the base-10 logarithm of the ratio, and then multiply it by a scaling factor (either 10 or 20). For voltage systems, such as our voltage amplifier, the expression becomes:

$$\text{dB} = 20 \log_{10} (U_o / U_{in}). \quad (1)$$

Despite the fact that we have mathematically massaged the ratio by converting it to a logarithm, the decibel is still

nonetheless nothing more than a means for expressing the ratio between two signals. Thus, a voltage gain of 12 can also be expressed as a gain of 21.6 dB (take your calculator and work out the example).

A similar expression can be used for current amplifiers, where the gain ratio  $I_o / I_{in}$  replaces the voltage ratio in equation (1).

For power measurements we need a modified expression to account for the fact that power is proportional to the square of the voltage or current:

$$\text{dB} = 10 \log_{10} (P_o / P_{in}) \quad (2)$$

Decibel notation prescribes a positive sign for a signal gain, and a negative sign for a signal loss. You will see this effect if you calculate either of the two equations above with an output signal level that is less than the input signal level. Thus, if the voltage amplifier gain is 12, the ratio of signals is 12/1, and the dB notation is 21.6 dB. But if the circuit is a 12-dB attenuator, the ratio is 1/12, and the expression works out to be -21.6 dB.

### Adding it all up

So why bother converting seemingly easy to handle, dimensionless numbers like voltage or power gains to a logarithmic number like decibels? Fair question. The answer is that it makes calculating signal strengths in a larger circuit or system a lot easier. To see this effect, let us consider the multistage system in Fig. 1. Here we have a hypothetical electronic circuit in which there are three amplifier stages and an attenuator pad. The stage

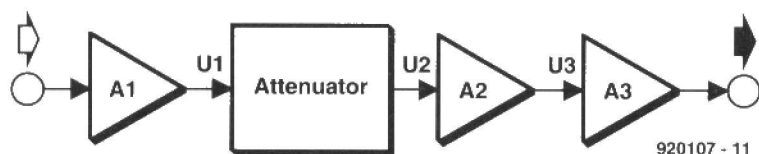


Fig. 1. Cascade amplifier and attenuator chain.



**Table 1. Common gains/losses expressed in decibels (dB).**

Ratio (out/in)	Voltage gain (dB)	Power gain (dB)
1/1000	-60	-30
1/100	-40	-20
1/10	-20	-10
1/2	-6.02	-3.01
1	0	0
2	+6.02	+3.01
5	+14	+7
10	+20	+10
100	+40	+20
1,000	+60	+30
10,000	+80	+40
100,000	+120	+60

gains are as follows:

$$\begin{aligned}
 A_1 &= U_1 / U_{in} = 0.2 / 0.010 = 20 \\
 \text{Atten} &= U_2 / U_1 = 0.1 / 0.2 = 0.5 \\
 A_2 &= U_3 / U_2 = 1.5 / 0.1 = 15 \\
 A_3 &= U_o / U_3 = 6 / 1.5 = 4
 \end{aligned}$$

The overall gain is the product of the stage gains in the system:

$$\begin{aligned}
 A_v &= A_1 \times \text{Atten} \times A_2 \times A_3 \\
 &= (20) \times (0.5) \times (15) \times (4) = 600.
 \end{aligned}$$

When converted to dB, the gains are expressed as:

$$\begin{aligned}
 A_1 &= 26.02; \text{Atten} = -6.02; A_2 = 23.52; \\
 &\text{and } A_3 = 12.04.
 \end{aligned}$$

The overall gain of the system (in dB) is the sum (not product) of these numbers:

$$\begin{aligned}
 A_{\text{v(dB)}} &= A_1 + \text{Atten} + A_2 + A_3 \\
 &= (26.02) + (-6.02) + (23.52) + \\
 &\quad (12.04) \\
 &= 55.56 \text{ dB}.
 \end{aligned}$$

The system gain calculated earlier was 600, and this number should be the same as above:

$$A_{\text{(dB)}} = 20 \log_{10}(600) = 55.56 \text{ dB},$$

i.e., they are the same.

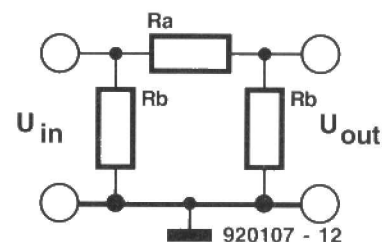
Converting from decibel notation to straight gain notation is simple: solve either the power or voltage decibel equation for the ratio  $U_o / U_{in}$  or  $P_o / P_{in}$ , as appropriate. For those who do not want to make the calculation, Table 1 shows common voltage and power gains and losses expressed both ways.

## Special dB scales

Various people have defined special dB-based scales that meet their own needs. They make a special scale by defining a certain signal level as '0-dB', and referencing all other signal levels to the defined 0-dB point. In the dimensionless dB scale, 0-dB corresponds to a gain of unity (see Table 1). But if we define '0-dB' as a particular signal level, then we obtain one of the special scales. The 'dBm' scale is often used in RF measurements, defines 0-dBm as one milliwatt (1 mW) of RF power dissipated in a 50-Ω resistive load.

## Attenuator circuits

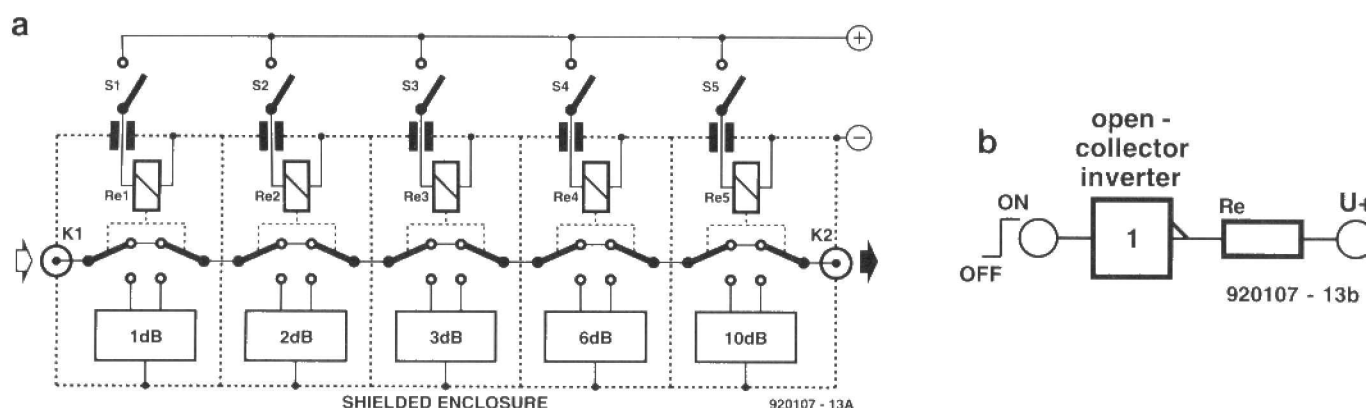
The basic circuit used for RF attenuators is the  $\pi$ -network of Fig. 2. This circuit is

**Fig. 2.**  $\pi$ -network RF attenuator pad.**Table 2. pi-attenuator resistor values**

Attenuation	$R_a$	$R_b$
1 dB	6.2 Ω	910 Ω
2 dB	12 Ω	470 Ω
3 dB	18 Ω	300 Ω
5 dB	33 Ω	200 Ω
10 dB	75 Ω	100 Ω
20 dB	270 Ω	68 Ω

unbalanced with respect to ground, so it can be used for coaxial RF systems.

The values of the resistors  $R_a$  and  $R_b$  (two  $R_b$  resistors are needed) determine the input / output impedances and the attenuation ratio. The calculation for the resistors values for very precise attenuators is quite complex, but those readers who want to try it are advised to consult a standard reference work such as *Reference Data For Radio Engineers*. If you use the same 5th edition that I own, check Chapter 10. Other readers might want to use the values shown in Table 2. The resistances are from the table of standard resistor values, so are easily obtained. The attenuation will be close to the values shown in the left-hand column of Table 2, but there will be a small error due to the use of standard resistor values, rather than the 'formula values' (which tend to come out with unlikely

**Fig. 3.** a) Circuit for a selectable step-attenuator; b) digital driver circuit to replace switches.

values like '31.234232  $\Omega$ '.

When building an RF attenuator, be sure to use the inherently non-inductive carbon composition or metal film resistors. Wirewound resistors tend to be inductors, so will not work well in RF circuits. Also, be sure to use 5% (gold colour code tolerance band), or better, tolerance resistors or the accuracy will suffer accordingly. The 1% resistors are best, but are hard to come by in quantities of less than fifty each.

Another alternative is to purchase ready-made commercial attenuators in standard attenuation values. I have used fixed attenuators made by Mini-Circuits (P.O. Box 350166, Brooklyn, N.Y., 11235-0003) for a number of projects over the years. They also make MMIC amplifier chips, double balanced mixers and other RF and microwave products. The attenuator to select will depend on your application; Mini-Circuits offers both coaxial in-line attenuators and printed circuit mounted attenuators.

Figure 3a shows a multi-stage step attenuator project that you can build. I built this one from five Mini-Circuits printed circuit mounted attenuators offering 1, 2, 3, 6 and 10 dB of attenuation. Note that each section of the attenuator is shielded from the other sections. This is an effort to prevent leakage of signal from one section to another, resulting in a loss of attenuation due to capacitive coupling.

The attenuators are switched in and out of the circuit by cross-connected double pole double throw (DPDT) switches. In one position, the switch shorts the signal path from input to output, while in the other position the attenuator is in series with the path.

You can use either manual DPDT toggle switches, or do like I did and use a small DPDT electromechanical relay as the switch. Parts catalogues can show you a number of relays, many of which are built in dual in-line package (DIP) format for use on IC printed circuit board, that will do the trick. Some of these relays operate from as low as 5 V DC, and as high as 12 V DC, so are compatible with a wide variety of applications. Because they contain diodes across the relay coil, the relays are polarity sensitive, i.e. they must be connected to the DC power supply correctly or damage can result (polarity markings are usually on the package).

One advantage of using relays for the switches in the step attenuator is that you can either switch them with manual SPST switches (as shown in Fig. 3a), or use digital drivers, such as the open-collector TTL inverter shown in Fig. 3b. When the inverter is used, it becomes possible to control the degree of attenuation used from a computer output or other digital circuit.

Figure 4 shows the construction of the multi-stage step-attenuator that I built.

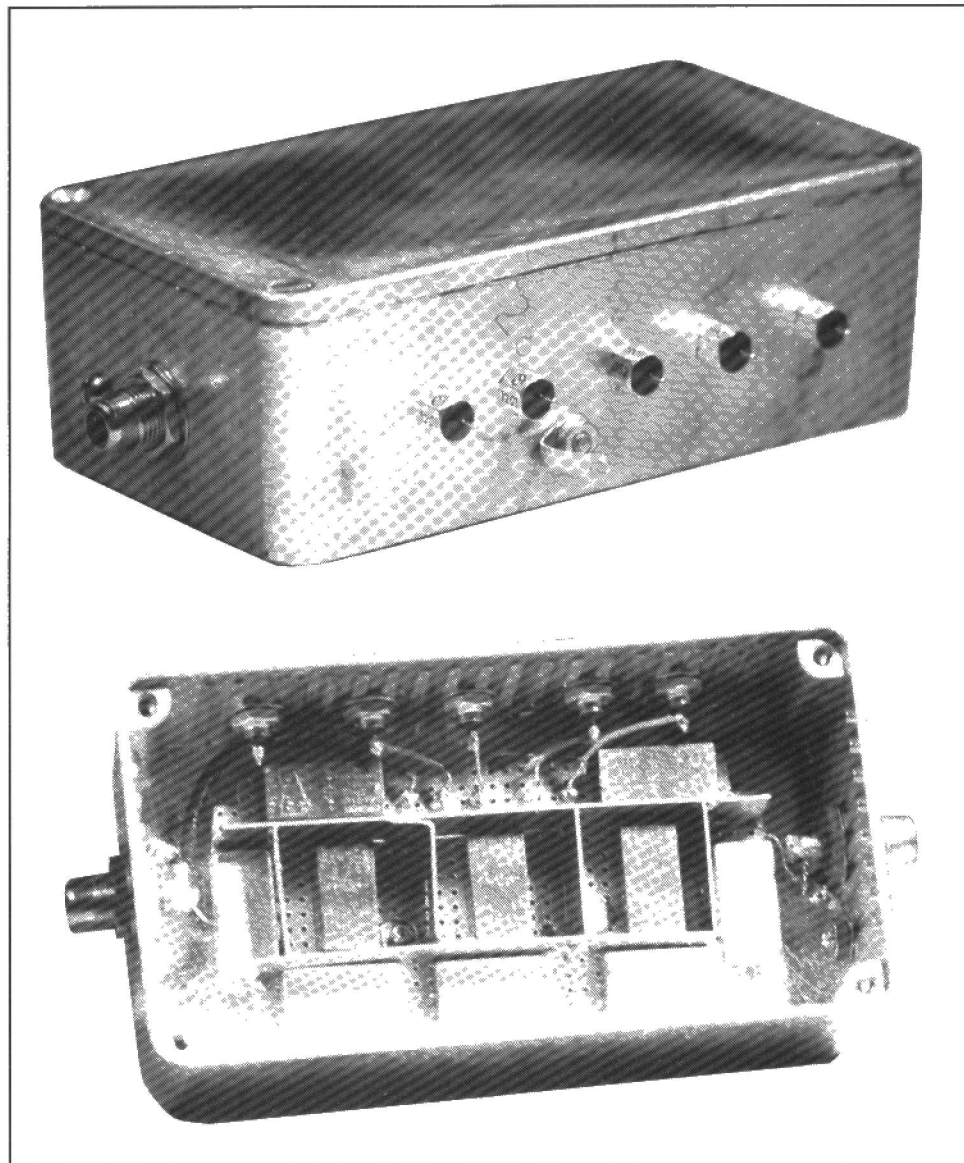


Fig. 4. Constructed project: a) outside view, b) inside view.

It is housed in a die-cast aluminum box (Fig. 4a) that is fitted with a tight cover to eliminate RF leakage (take a look at the box you buy, not all of them are well made and will leak RF if the cover is poorly fitted). The internal shields (Fig. 4b) are made from brass flat stock sheet metal obtained in a local hobby shop (the kind that cater to model plane and train builders). RCA phono jacks are used for input and output, but I recommend BNC or SO-239 UHF coaxial connectors for most readers (match the other instruments or circuits in your system).

A receiver application of the attenuator is shown in Fig. 5. Here we have a switchable attenuator in series with the antenna line to a receiver (the attenuator should be mounted as close as possible to the receiver antenna jack). If a strong signal overloads the receiver (which can cause all manner of messy problems), then cut the attenuator into the circuit while listening to the station (set switch S1 to the 'B' position). When you look for other, less strong stations, remove the attenuator from the circuit by setting switch S1 to the 'A' position. This circuit

will also work if you want to limit your tuning to strong stations, eliminating some of the crud underneath the blow-torches of the shortwave bands.

Another application is shown in Fig. 6. Here we see a monolithic microwave integrated circuit (MMIC) device that provides amplification from near DC to 2000 MHz. The particular device shown here is the Mini-Circuits

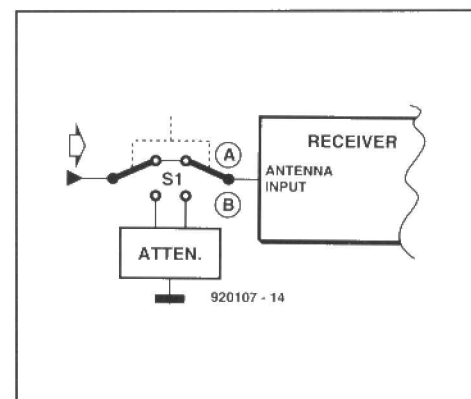


Fig. 5. Use of an attenuator with a receiver to reduce strong signals.

MAR-xx series, but there are others available on the market that are based on the same concept. One problem with very wide band amplifiers is that the complex impedances seen by the input and output ports are sometimes capable of creating instability in the amplifier. Impedance variations can be snuffed out by using the brute force method of inserting a 1-dB or 2-dB attenuator in the input and output lines (as shown in Fig. 6), as close as possible to the body of the amplifier IC device. The value given for resistor R1 applies when a supply voltage,  $V_+$ , of 9 V is used, and the amplifier IC is to work at 7 V. In all other cases, calculate R1 from

$$R1 = (V_+ - U_{amp}) / 0.015 \quad [\Omega] \quad (3)$$

Attenuators are also used in making comparison measurements in RF circuits. Very often, because we lack well calibrated RF test equipment, we use the S-meter on a receiver as a relative indicator, and then use precision attenuators to adjust signal levels. For example, if you want to measure the gain of an RF preamplifier, you might note the 'with' and 'without' S-meter readings, and then insert the attenuator to see how much the S-meter drops. With this information

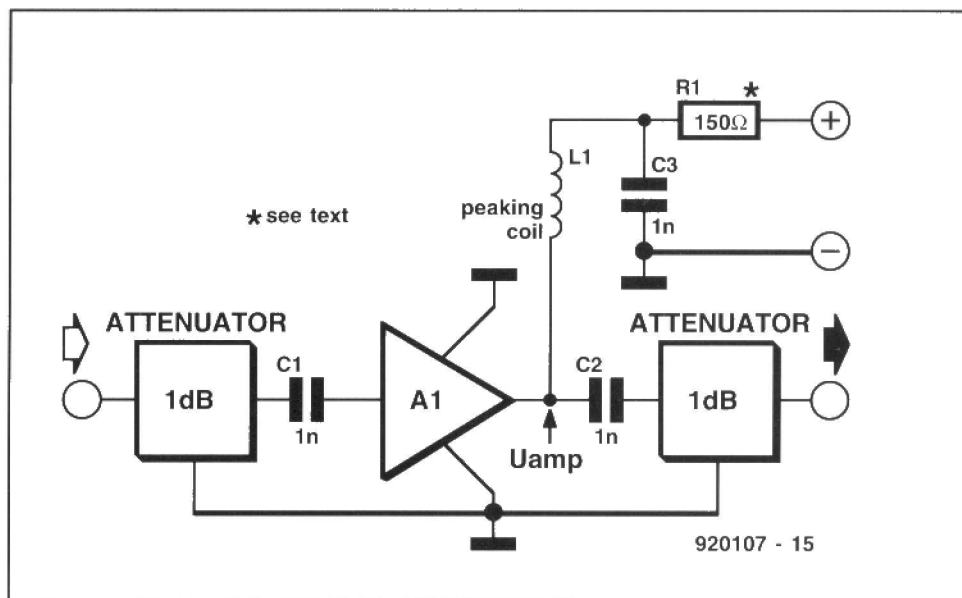


Fig. 6. Use of attenuators to stabilize wideband amplifiers.

you know the exact 'dB / S-unit' calibration of the meter.

RF workshop should be without a collection of these useful devices. ■

## Conclusion

RF attenuators are easy to build, and provide a lot of useful applications to the RF and ham radio experimenter. No good



## IF AN ADVERT IS WRONG, WHO PUTS IT RIGHT?

We do. The Advertising Standards Authority ensures advertisements meet with the strict Code of Advertising Practice. So if you question an advertiser, they have to answer to us.

To find out more about the ASA, please write to Advertising Standards Authority, Department X, Brook House, Torrington Place, London WC1E 7HN.



This space is donated in the interests of high standards in advertisements.

## ONLY WHILE STOCKS LAST

### 8051 DEVELOPMENT BOARD (MICRO ENGINE)

Contains socketed PLCC 80C31, Eeprom Socket, Xtal, Decoder IC and 18 pin IDC header with outputs from port 1 & 3. Complete with Circuit, including ASM51 Text Editor/Assembler and SIM8751/2 Simulator program for IBM PC. **was £99.95 Now only £39.95** State disk size.

### EPROM/ROM Emulator

Works on any computer with centronics printer port. Emulates all Roms (switchable) from 1K(2708 to 32K (27256)) **was £89.95 Now Only £39.95**

### AUTO TRACKS V6 PPCB Designer

Produce professional printed circuit boards quickly and easily on you IBM PC. Features include: Auto Routing, Rats Nest, User defined Library, Single or double-sided boards, printer output to 9/24 pin Epson.

Cannot be repeated at this price, **was £59.95 Now only £19.95** State disk size.

### COMPONENTS

LED 7 Seg Displays CA. 05 inch **0.25p ea**  
LCD 40 Char x 2 lines sim LM018L with data **£8.00**  
SC80C51 40 pin CPU **£1.25 ea**  
M80C31 PLCC CPU with socket **£2.95 ea**  
12 pole 1 way or 3 pole 4 way Rotary Switches **£0.25p ea**

Please include £1.50 Postage/Packing per order

JOHN MORRISON (MICROS) Dept EI,  
4 REIN GARDENS, TINGLEY, WEST YORKSHIRE,  
WF3 1JR. TELEPHONE: 0532 537507



**CATALOGUE  
NOW FREE**

# CRICKLEWOOD ELECTRONICS

**CRICKLEWOOD ELECTRONICS LTD, 40 CRICKLEWOOD BROADWAY, LONDON NW2 3ET**  
Tel: 081 452 0161 Fax: 081 208 1441

BOOKS 	BOXES & CASES 	CABLE & WIRE 	CAPACITORS 	CONNECTORS 	KITS 
RESISTORS 	SEMI-CONDUCTORS 	SPEAKERS 	VIDEO HEADS 	SWITCHES 	TOOLS & BENCHMARK 

SEND NOW FOR THE **CRICKLEWOOD** COMPONENT CATALOGUE  
ONE OF THE BEST RANGES AVAILABLE

Name.....  
Address.....  
.....  
.....  
.....



# DIGITAL-AUDIO ENHANCER

Design by T. Giesberts

**When a variety of audio equipment (CD drive, D-A converter, CD player, DAT recorder) is connected together, jitter may often be present on the signals between the various units. Investigations have shown that although most people cannot hear jitter, it can be measured. The enhancer resulting from these investigations ensures that the digital signals are free of jitter.**

The digital audio signals considered here are of the S/PDIF format as shown in Fig. 1 and 2. The bits to be transmitted are contained in the data signal, which is 'modulated' by the clock, resulting in the biphasic mark signal—see Fig. 1. In this signal, a logic 1 is represented by a high-low transition (or a low-high transition) half-way through the bit. In this way the ones and zeros are not represented by levels but by the distances between individual transitions. The advantage of this signal is that it contains not only the data, but also the clock rate at which the data are transmitted. Knowing this rate is essential for the processing of the data after reception.

This signal is still not of the S/PDIF format, for in that each 32-bit word (subframe) is preceded by a preamble. This preamble is a fixed pattern of successive, non-modulated logic levels. The disruption of the biphasic modulation is used for synchronization of the decoder. The preamble also shows the decoder what data are contained in the next word and whether the word is the start of a frame (1 frame=384 words). To ensure a smooth transfer to the modulated data, the preamble may also be inverted, depending on the logic level at which the preceding word ended—see Table 1.

## What is jitter?

Jitter occurs when a transition (edge) of a pulse is not exactly on time. It is a kind of frequency modulation that may be compared with the wow and flutter of analogue signals. It may also be noise or an FSK-like modulation on the clock signal. Analysis of such a signal shows that it consists of components as shown in Fig. 3. The top waveform indicates that the clock has two frequency components; the centre waveform is typical of a noise-like variation in the clock signal; the bottom graph shows what the clock should be: a single, stable frequency.

Jitter is produced partly in the equipment that provides the audio signal.

Apparently, not all such equipment has a stable clock. Another source of jitter is the analogue transition of the data signal. Analogue? However you look at it, the signal, be it a voltage, a current, or a light-beam, passes through a cable with limited bandwidth and other deleterious properties. The first to be affected by these disruptive characteristics are the transitions (edges) of the signal. The restoring of these transitions after re-

ception may not be wholly correct. In our investigation, the decoding of the clock signal from the biphasic-modulated signal in several commercial units was affected by the preamble. This is because the 'not biphasic' appearance of the preamble distorts the clock signal that is integrated with the data signal. When that clock is extracted with a straight phase-locked loop—PLL, problems arise because the PLL tends to track the distur-

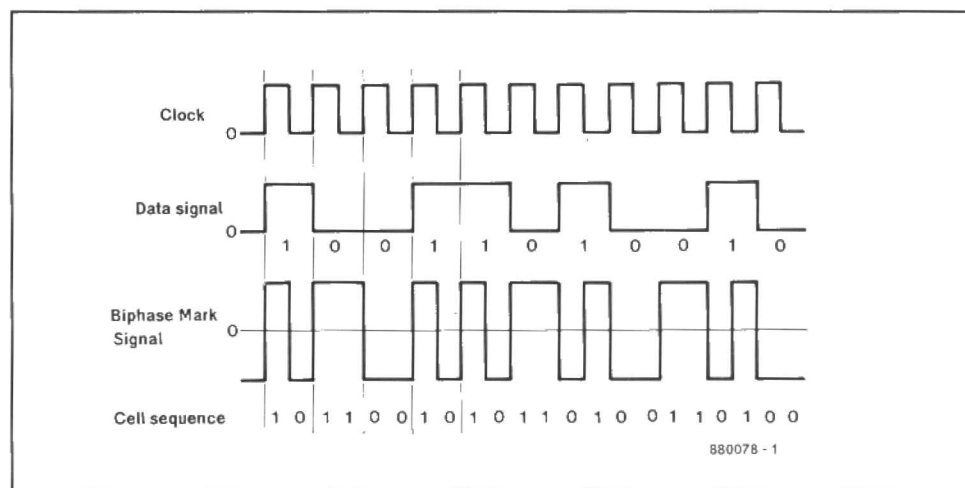


Fig. 1. In signals of the S/PDIF format, the data are biphasic modulated.

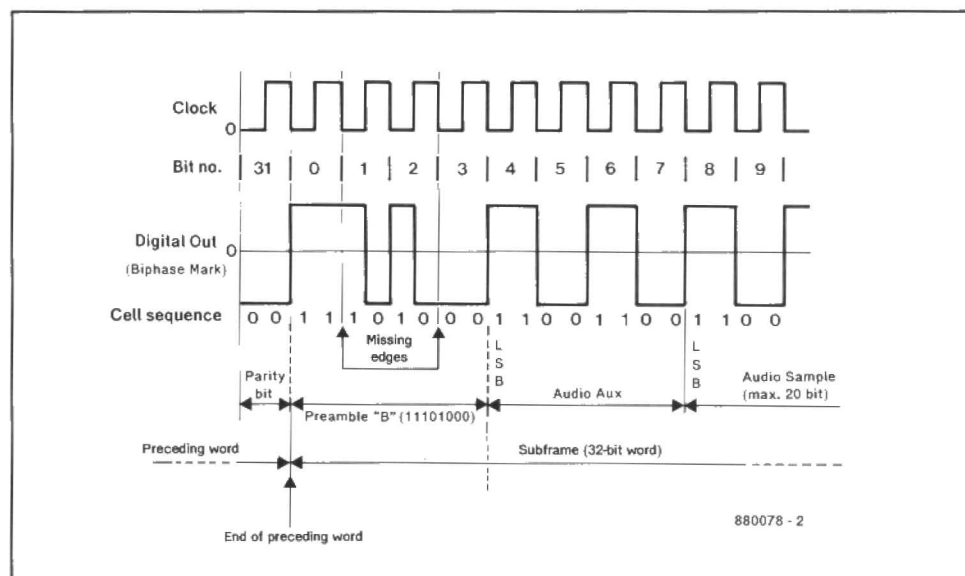


Fig. 2. Another constituent of the S/PDIF signal is the preamble that precedes each and every 32-bit word.

Preamble	Previous cell 0	Previous cell 1	Word content
B	11101000	00010111	data left channel
start of frame			
M	11100010	00011101	data left channel
W	11100100	00011011	data right channel

Table 1. Cell sequence with the preamble.

Fig. 3. Depending on the source of the jitter, the clock signal may consist of 2 (or more) discrete frequencies or a band of noise. The perfect clock is a single, stable frequency.

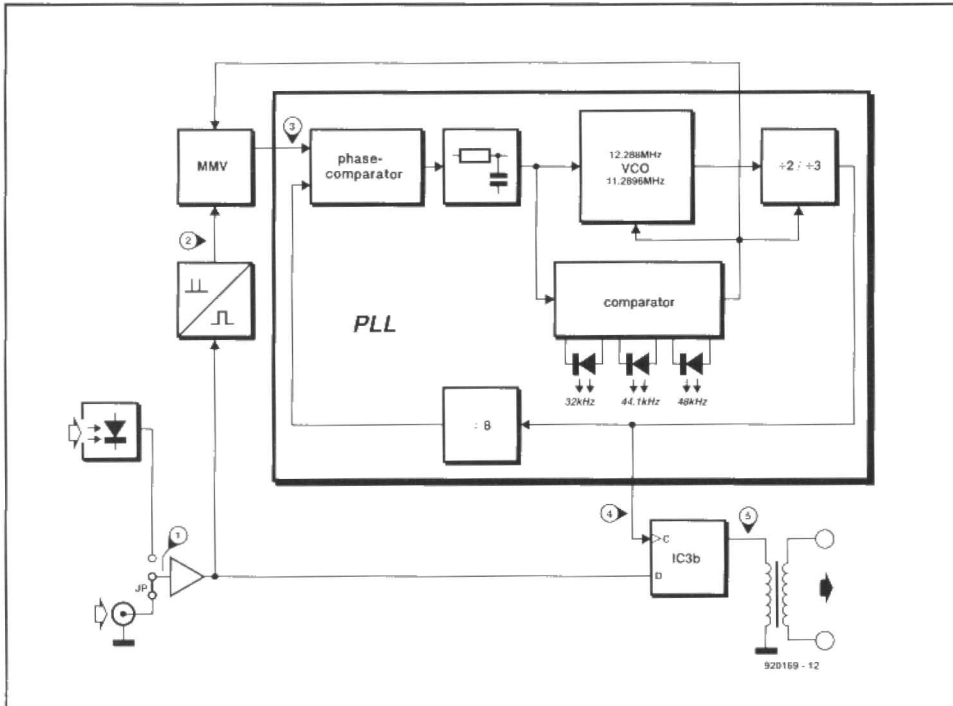
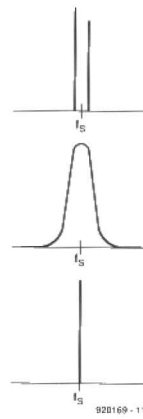


Fig. 4. Block diagram of the digital audio enhancer.

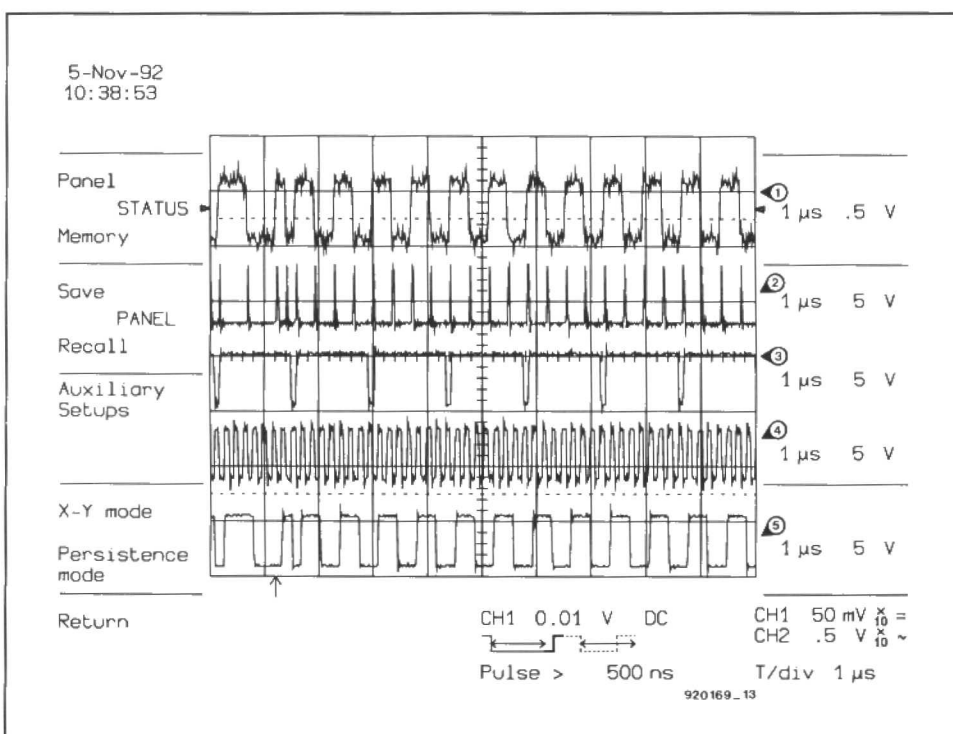


Fig. 5. Oscilloscope of the five signals highlighted in Fig. 4.

tion. The same problem was encountered early on during the design of the present enhancer.

## Blocking jitter

The enhancer, whose block diagram is given in Fig. 4, is based on bistable IC<sub>3b</sub>. The remainder, pulse shaper, MMV and PLL serve to produce a clock that is as nearly free of jitter as is possible.

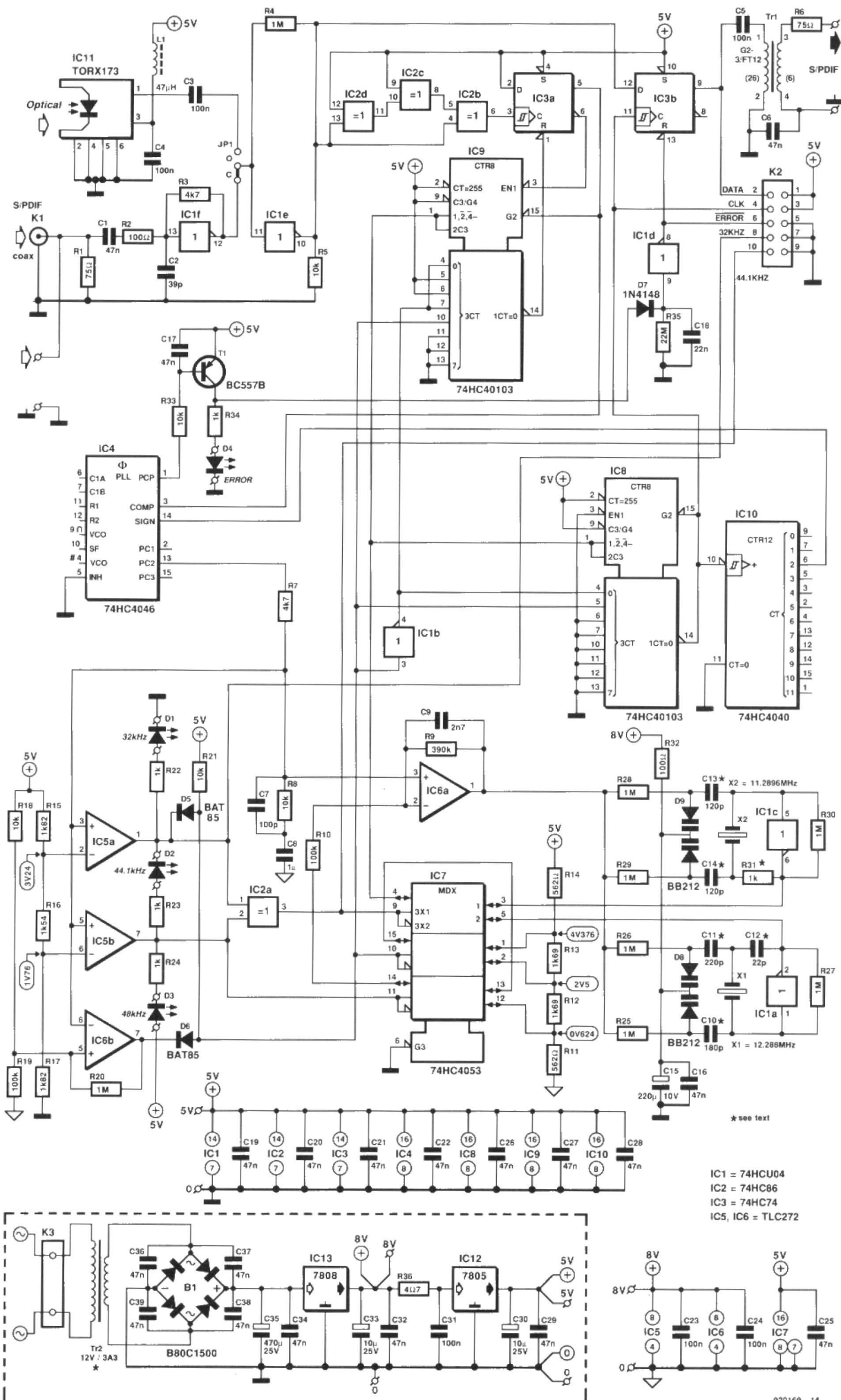
The PLL produces from the input signal a clock signal that is highly stable and, of course, synchronous with the original clock. The new clock ensures, however, that the bistable passes the input signal to the output only when the data at the input have assumed a stable level after a possibly frayed transition. In other words, the output signal derives its transitions from the voltage-controlled oscillator—VCO—in the PLL and its data from the input signal.

The operation is, therefore, fairly simple, but the design is not. It is clear that most of the electronic circuitry is required to produce a highly stable clock. In fact, three clock frequencies are needed: 32 kHz, 44.1 kHz and 48 kHz. The action is shown by combining the various signals in Fig. 4 (numbered 1–5) in Fig. 5. The signals were measured in the prototype with a digital oscilloscope.

At the top is part of the input signal that has been amplified to TTL level. It contains preamble 'M' (11100010) followed by a number of databits that are all zero. The next step in the preparation of the clock signal is the production of short pulses on each transition of the input signal. Although the signal appears perfectly usable, bear in mind that the data bits are all zero. Each logic 1 in the data signal, and also in the preamble, upsets the regularity.

Regularity is sought and found by a non-retriggerable monostable multivibrator—MMV. Setting the MMV is a question of finding the smallest common denominator. In Fig. 1, it was seen that each bit is sent in two halves: two cells. To negate the difference between logic 1s and 0s, the design must be geared to the duration of two cells. Also, the preamble must not have any effect. As we have seen, the preamble has a duration of eight cells and occurs after every 32 bits, i.e., 64 cells. This means that the smallest common denominator is the duration of eight cells, since eight cells equal four times two cells, and are exactly an eighth of 64 cells.

Based on this, the MMV has been designed so that it is triggered at every eighth cell. During seven cells, its output (signal 3) is high and it cannot be triggered. After the onset of the seventh cell, the MMV changes state, so that it can be triggered at the next (eighth) cell. As can be seen, there is no irregularity in the output of the MMV. It is noteworthy that the MMV seeks the correct trigger in-





stants, even during the initial synchronization phase of the circuit.

Although the output of the MMV is free of spurious frequency components, it may still contain jitter and, furthermore, its frequency is eight times too low. Both these complications are removed by a PLL. This circuit multiplies the frequency by eight and acts as a filter that reduces the jitter to nought for all practical purposes. The result is a very stable clock (signal 4 in Fig. 4 and 5). The first transition of this pulse is used to clock data bistable IC<sub>3b</sub>. This transition occurs just after the onset of a cell in the input signal. The output of the bistable (signal 5 in Fig. 4 and 5) is thus a signal whose level is derived from the input, but whose transitions are 'new'. Note that the irregular reproduction of the clock on the oscillogram is caused by the digital scope. This instrument was not able to faithfully reproduce the very short (compared with the other signals) periods of the clock.

As you will know, digital audio processing requires three clocks (sampling frequencies): 32 kHz, 44.1 kHz and 48 kHz. This makes the timing of the circuits, which is determined by the PLL, quite complicated.

The PLL contains a crystal-controlled VCO (Voltage Controlled Oscillator). The control voltage for this circuit is divided into three ranges: one for each sampling frequency. From this voltage, a comparator can determine the clock frequency of the input signal.

The output of the comparator is used to set the VCO, a scaler and the MMV. The combination of VCO and scaler makes it possible to obtain three sampling frequencies from two crystal frequencies. Note that designs using one crystal to generate three frequencies, and those using three crystals require more components than the present design.

The sampling frequency,  $f_s$ , must be doubled, because each sample must cater for the left-hand channel and for the right-hand channel. Then, it must be multiplied by 64, since each sample, after modulation, consists of 64 cells. The frequency so obtained is that at which the bistable is clocked. The crystal frequency,  $f_c$ , is twice or three times that frequency (2 or 3 is the divisor of the scaler between the VCO and the bistable). That is,

$$f_c = f_s \times 2 \times 64 \times 2,$$

or

$$f_c = f_s \times 2 \times 64 \times 3.$$

These calculations yield a crystal frequency of 12.288 MHz for sampling fre-

quencies of 32 kHz and 48 kHz, and of 11.2986 MHz for a sampling frequency of 44.1 kHz.

## Circuit description

The input of the circuit—see Fig. 6—may be optical via IC<sub>1</sub> or coaxial via K<sub>1</sub>. Jump lead JP<sub>1</sub> must be set accordingly. The (0.5 V<sub>pp</sub>) signal at the coaxial input is raised to TTL level by IC<sub>1f</sub>.

The signal is then amplified by IC<sub>1e</sub>, from where it is passed to bistable IC<sub>3b</sub>, whose action has already been discussed. The output of the bistable is applied to a transformer, where the signal level is (re)converted to coax level.

Apart from to the bistable, the output of IC<sub>1e</sub> is applied to a pulse shaper consisting of XOR gates IC<sub>2b</sub>–IC<sub>2d</sub>. The signal to one input of IC<sub>2b</sub> is delayed by IC<sub>2c</sub>–IC<sub>2d</sub>, while that to the other input is direct. This means that at every change of level the data at the inputs of IC<sub>2b</sub> are unequal for a short instant, which results in the output of IC<sub>2b</sub> briefly going high at each transition of the input signal.

The MMV, which has been discussed already, is composed of bistable IC<sub>3a</sub> and down counter IC<sub>9</sub>. The bistable is set via the clock input that serves as trigger input for the MMV. The bistable is reset by the down counter, which in this way thus determines the on time of the MMV. Since in this arrangement the input signal can influence the bistable only when this has been reset by the counter, the MMV is not retriggerable.

The MMV action is as follows. When the bistable is not set, it enables terminal C3/G4 of IC<sub>9</sub> for asynchronous inputting. The number that is input will be discussed later. When the bistable is set, the counter is enabled via EN1 and counts down to zero in rhythm with the VCO frequency. At the instant the counter status becomes zero, the CT=0 output also becomes zero, whereupon the bistable is reset.

As already discussed, the VCO frequency is two or three times as high as the frequency that clocks each data cell into bistable IC<sub>3a</sub>. Furthermore, the MMV is quiescent after the seventh and before the eighth cell. Considered in clock pulses for IC<sub>9</sub>, that is after the 14th or 21st and before the 16th or 24th. The design uses the 15th and the 22nd clock pulse. In other words, IC<sub>9</sub> is preset at 15 or 22 via the data inputs. This is effected by two control lines that are each other's inverse (inverter IC<sub>1b</sub>) and are derived from the comparator in the PLL.

The non-inverting output of IC<sub>3a</sub> is also the output of the MMV, which is linked to phase comparator IC<sub>4</sub>. This stage compares the clock derived from the input signal with the new clock. The re-

sult of this comparison appears as pulses at pin 13, which are applied to the loop filter of the PLL: R<sub>7</sub>–R<sub>8</sub>–C<sub>7</sub>–C<sub>8</sub>. This low-pass filter converts the pulses into a direct voltage that is used for fine control of the VCO. Because of the filter, the VCO reacts only to long or large deviations, such as a different sampling frequency, but is insensitive to short and small deviations, such as jitter. The second comparator output is amplified by T<sub>1</sub>, whose output is used to drive an LED. This diode indicates whether the frequencies at the comparator inputs are equal or not.

Detecting to which input frequency the circuit should lock is effected by splitting the control voltage provided by the loop filter into three ranges: 0.5–1.5 V for 48 kHz; 2–3 V for 44.1 kHz; and 3.5–4.5 V for 32 kHz, and using two comparators, IC<sub>5a</sub> and IC<sub>5b</sub>, to react to these ranges. The thresholds of the comparators lie at 1.76 V and 3.24 V. The outputs of the comparators are applied to D<sub>1</sub>–D<sub>3</sub> that indicate which sampling frequency has been detected. The LEDs are connected to the comparators in such a manner that only one can light at a time.

As has already been stated, only two VCOs, IC<sub>1a</sub> and IC<sub>1e</sub>, are used to generate three frequencies. Basically these two oscillators are identical. Their control voltage is derived from the loop filter via IC<sub>6a</sub>, which deducts an offset from this voltage and amplifies the resulting potential  $\times 5$ . In this manner, the ranges of 1 V per sampling frequency are converted to one range of 0–5 V. The offset is derived from potential divider R<sub>11</sub>–R<sub>14</sub> via electronic switch IC<sub>7</sub>. This switch also ensures that the correct VCO is connected to the clock input of counters IC<sub>8</sub> and IC<sub>9</sub>.

Earlier, it was stated that in the timing of the MMV it has to be ensured that the circuit reacts correctly to the sampling frequencies. Comparator IC<sub>6b</sub>, which has a threshold of 4.55 V, that is, just outside the control range for 32 kHz, prevents erroneous operation if the circuit is set to the 32 kHz mode and a 44.1 kHz signal is input. In that situation, the output of IC<sub>6b</sub> becomes low, so that the AND gate formed by D<sub>5</sub>–D<sub>6</sub>–R<sub>11</sub> prevents the output of IC<sub>5a</sub> becoming high. The divisors of IC<sub>8</sub> and IC<sub>9</sub> are then, correctly, switched to 2 and 15 respectively.

Since the 1CT=0 output of IC<sub>9</sub> is linked to the synchronous preset, G2, of IC<sub>8</sub>, this counter counts down to zero. Because it has to operate as a  $\div 2$  or a  $\div 3$  scaler, numbers 1 and 2 have to be added, for which purpose the clock is used. The output of IC<sub>8</sub> is applied to bistable IC<sub>3b</sub>, where it is used for removing the jitter, and to  $\div 8$  scaler IC<sub>10</sub>, which feeds the signal back to the phase comparator.

To prevent mutilated data being output when the PLL has not yet been syn-

**Fig. 6. Circuit diagram of the enhancer. Although the principle of operation is simple, the requirement for three different clock frequencies necessitates the use of quite a few components.**

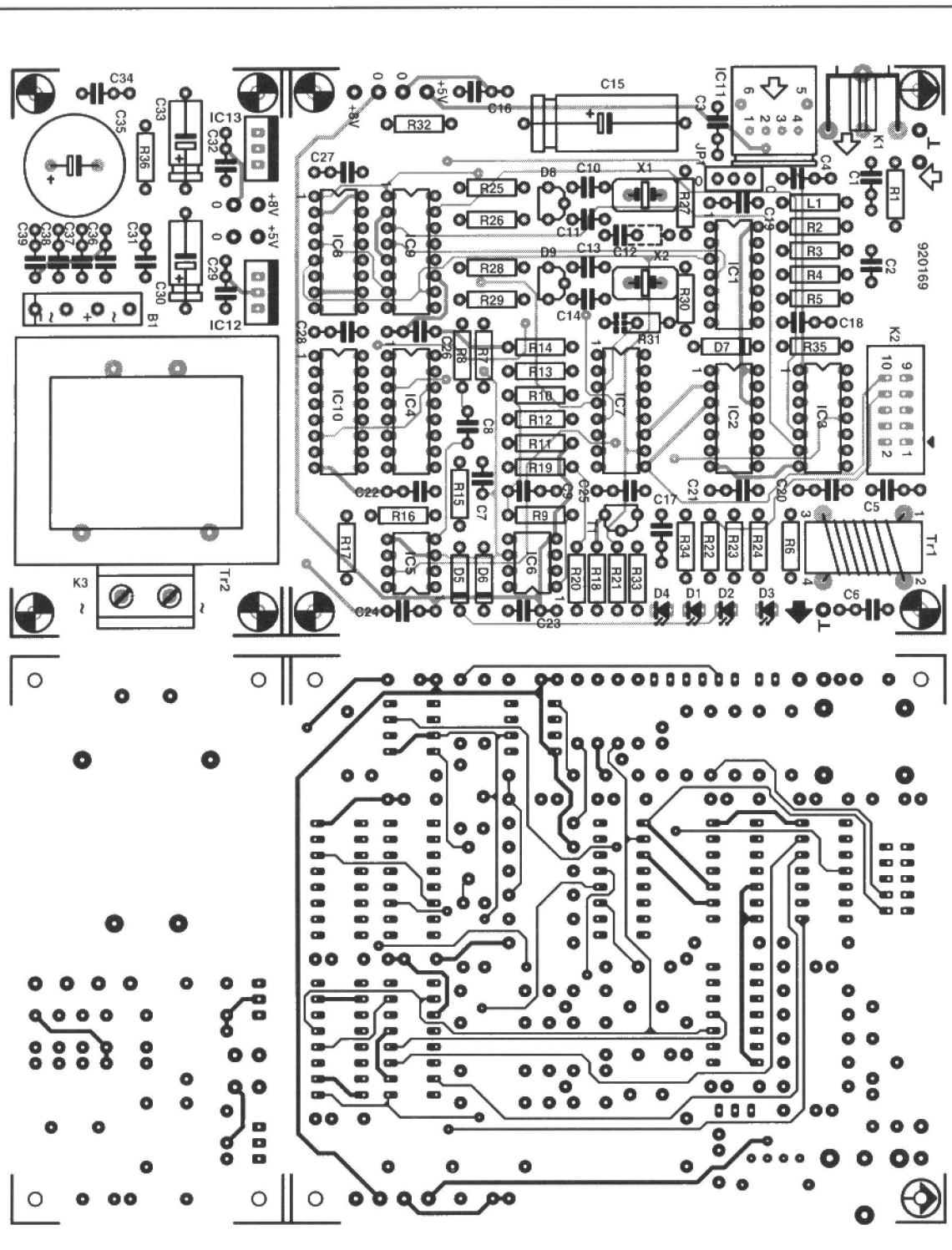


Fig. 7. Printed-circuit board for the enhancer: component side.

chronized, the control signal of  $D_4$  is used to keep  $IC_{9b}$  reset via inverter  $IC_{1d}$ . Pulse-stretching network  $D_7$ - $R_{35}$ - $C_{18}$  prevents the short control pulses of the PLL, which may temporarily be present on this signal, reaching the bistable during the synchronization process.

All that needs to be noted regarding the conventional power supply is that the input voltage of  $IC_{13}$  must be not less than 11 V nor more than 15 V. This means that, since the enhancer draws hardly any current, a transformer with a 9 V secondary may be used (which in these conditions provides about 12–13 V).

## Construction

Although construction of the unit on the printed-circuit board shown in Fig. 7 is straightforward, a few points should be noted. Do not mount the crystals too close to the board to avoid any risk of their being short-circuited by the tracks. Preferably, insulate them from the board. If the VCOs do not oscillate readily, use either 22 pF capacitors or 1 k $\Omega$  resistors in the  $C_{12}$ / $R_{31}$  positions. It may also be necessary to change the values of  $C_{10}$ - $C_{11}$  and  $C_{13}$ - $C_{14}$ , so that the control voltage at pin 1 of  $IC_{6a}$ , when the circuit is locked,

is about 2.5 V.

Transformer  $Tr_1$  is a DIY device that is wound on a Type G2-3/FT12 toroidal core that has also been used in several recent audio & hi-fi projects. Close-wind 26 turns of 0.5 mm dia. enamelled copper wire on to the core and solder the ends to terminals 1 and 2. Then, lay 6 turns of the same type of wire over the earlier turns and solder their ends to terminals 3 and 4. Note that the transformer (and  $C_5$ ,  $C_6$  and  $R_6$ ) are not needed if the enhancer is built into the digital-to-analogue converter. In that case, the data signal can then be taken from  $K_2$  (at TTL level),

## PARTS LIST

### Resistors:

$R_1$ ,  $R_6$  = 75  $\Omega$ , 1%  
 $R_2$ ,  $R_{32}$  = 100  $\Omega$   
 $R_3$ ,  $R_7$  = 4.7 k $\Omega$   
 $R_4$ ,  $R_{20}$ ,  $R_{25}$ - $R_{30}$  = 1 M $\Omega$   
 $R_5$ ,  $R_8$ ,  $R_{18}$ ,  $R_{21}$ ,  $R_{33}$  = 10 k $\Omega$   
 $R_9$  = 390 k $\Omega$   
 $R_{10}$ ,  $R_{19}$  = 100 k $\Omega$   
 $R_{11}$ ,  $R_{14}$  = 562  $\Omega$ , 1%  
 $R_{12}$ ,  $R_{13}$  = 1.69 k $\Omega$ , 1%  
 $R_{15}$ ,  $R_{17}$  = 1.82 k $\Omega$ , 1%  
 $R_{16}$  = 1.54 k $\Omega$ , 1%  
 $R_{22}$ - $R_{24}$ ,  $R_{34}$  = 1 k $\Omega$   
 $R_{31}$  = 1 k $\Omega$  (see text)  
 $R_{35}$  = 22 M $\Omega$

### Capacitors:

$C_1$ ,  $C_6$ ,  $C_{16}$ ,  $C_{17}$ ,  $C_{19}$ - $C_{22}$ ,  
 $C_{25}$ - $C_{29}$ ,  $C_{32}$ ,  $C_{34}$ ,  $C_{36}$ - $C_{39}$   
 = 47 nF, ceramic  
 $C_2$  = 39 pF  
 $C_3$ - $C_5$ ,  $C_{23}$ ,  $C_{24}$ ,  $C_{31}$  = 100 nF,  
 ceramic  
 $C_7$  = 100 pF  
 $C_8$  = 1  $\mu$ F  
 $C_9$  = 2.7 nF  
 $C_{10}$  = 180 pF (see text)  
 $C_{11}$  = 220 pF (see text)  
 $C_{12}$  = 22 pF (see text)  
 $C_{13}$ ,  $C_{14}$  = 120 pF (see text)  
 $C_{15}$  = 220  $\mu$ F, 10 V  
 $C_{18}$  = 22 nF  
 $C_{30}$ ,  $C_{33}$  = 10  $\mu$ F, 25 V  
 $C_{35}$  = 470  $\mu$ F, 25 V, radial

### Inductors:

$L_1$  = 47  $\mu$ H  
 $Tr_1$  = see text

### Semiconductors:

$D_1$  = LED, green\*  
 $D_2$  = LED, yellow\*  
 $D_3$ ,  $D_4$  = LED, red\*  
 $D_5$ ,  $D_6$  = BAT85  
 $D_7$  = 1N4148  
 $D_8$ ,  $D_9$  = BB212  
 $B_1$  = B80C1500  
 $T_1$  = BC557B  
 $IC_1$  = 74HC004  
 $IC_2$  = 74HC86  
 $IC_3$  = 74HC74

IC4 = 74HC4046

IC5, IC6 = TLC272

IC7 = 74HC4053

IC8, IC9 = 74HC40103

IC10 = 74HC4040

IC11 = TORX173

IC12 = 7805

IC13 = 7808

#### Miscellaneous:

JP1 = 3-way header with jumper

K1 = audio socket for PCB

K2 = 10-way male box header

K3 = 2-way terminal block,  
pitch 7.5 mm

X1 = crystal 12.288 MHz

X2 = crystal 11.2896 MHz

Tr2 = mains transformer, 3.3 VA  
9 V secondary (see text)

\*high-efficiency type

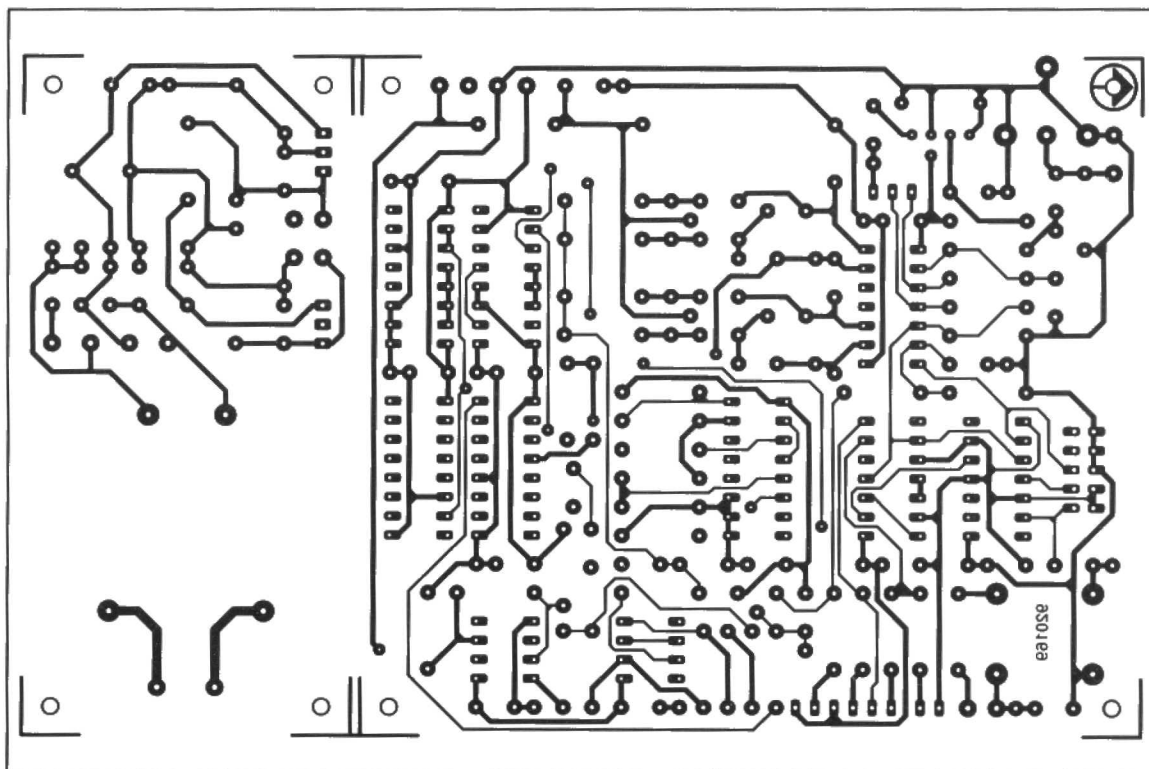


Fig. 7. Printed-circuit board for the enhancer: track side.

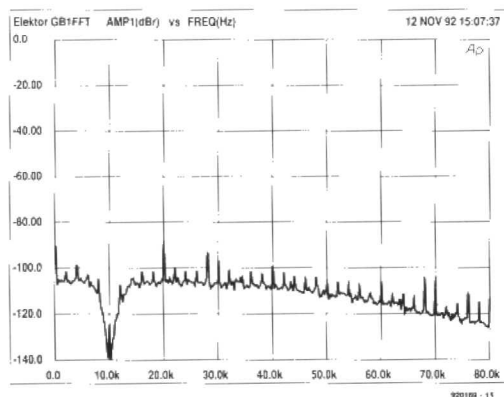


Fig. 8. Spectrum of spurious signals – optical link, no enhancer.

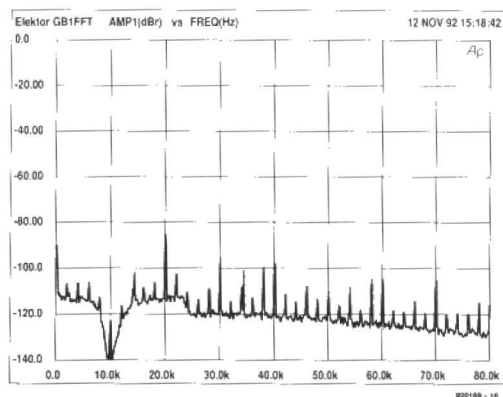


Fig. 9. Spectrum of spurious signals – optical link with enhancer.

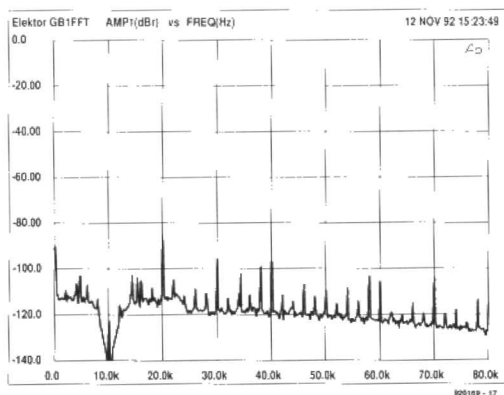


Fig. 10. Spectrum of spurious signals – coax link, no enhancer.

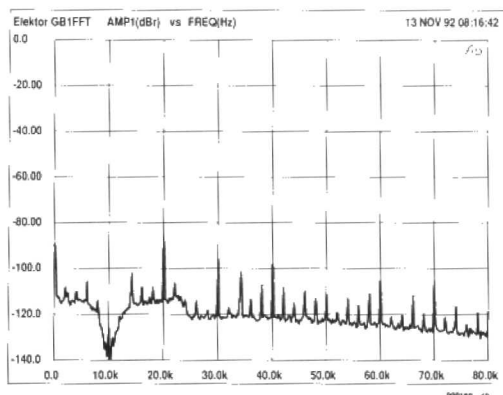


Fig. 11. Spectrum of spurious signals – coax link with enhancer.

or a wire link may be laid from the C<sub>5</sub> to R<sub>6</sub> positions on the board.

The enhancer, if not built in, must be connected to the digital-to-analogue converter with as short a coax cable as possible.

## Test results

The test signal used was a 10 kHz signal with a sampling frequency of 48 kHz

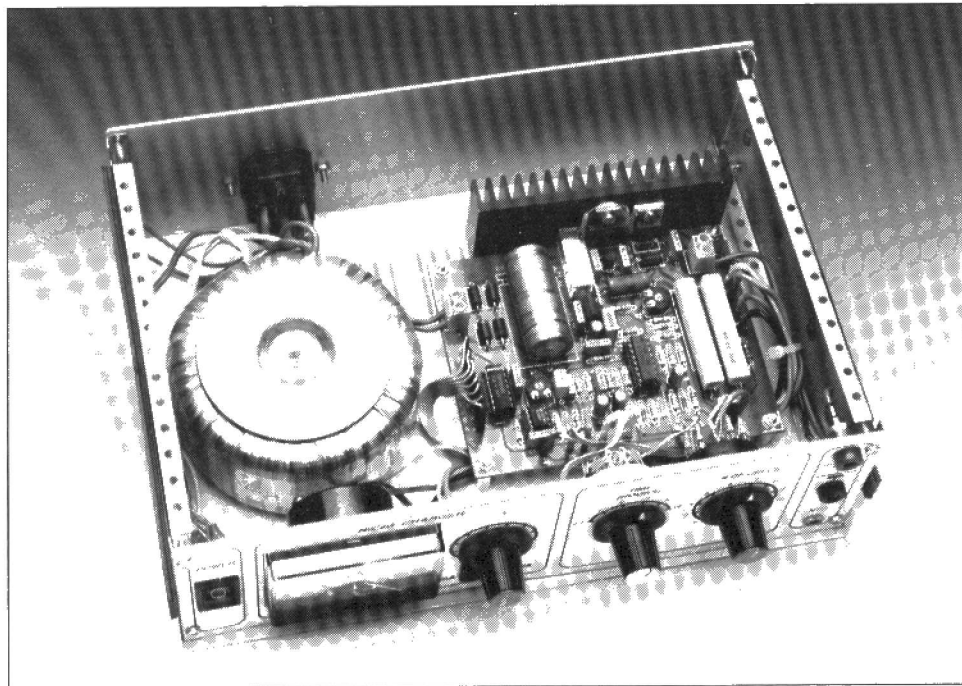
derived from a DAT recorder. This signal was applied via an optical cable and subsequently via a coax cable to the digital-to-analogue converter, first without the enhancer and then with it in both cases. It should be borne in mind that jitter is at least 100 dB below the level of the test signal. The analogue output of the converter was fed to a spectrum analyser after the 10 kHz signal had been removed with the aid of a high-quality

notch filter to ensure that only the spurious remnants were analysed. The results are shown in Fig. 8–11: 8 and 9 relate to an optical connection between the DAT recorder and the D-A converter, and 10 and 11 to a coax connection. It will be seen that with the optical connection the enhancer improves the signal, whereas with the coax connection there is little difference between tests with and without the enhancer. ■



# U2400B NiCd BATTERY CHARGER

Design by U. Bangert and W. Ernst



The battery charger takes its name from the IC it is based on: the well-known Type U2400B processor. This IC was designed primarily for use in battery chargers and is, therefore, equipped with a number of specific features.

The processor controls the charging for a preset time at constant current, provided, of course, that the battery was fully discharged before charging began. To make certain that this is always so, the operation always starts with discharging the battery entirely. To that end, pin 10 of the device—see Fig. 1—is made logic high. An internal stage connected to this pin causes the battery to be discharged until the voltage at pin 6 has dropped to 0.525 V. At that instant, pin 10, and immediately thereafter pin 12, goes low and charging can begin. The low level at pin 12 serves to actuate charging circuit  $T_2$ - $T_3$ . After charging at full current has taken place for a predetermined time, trickle charging begins. Trickle charging, which may continue for a long period of time, ensures that the battery capacity does not degrade during the life of the battery. It is effected by the processor driving pin 12 low for 100 ms every 16.8 s, which means that effectively the average charging current is reduced to  $6/1000$  of its peak value.

The initial discharge facility may be disabled by connecting pin 6 to earth. This will be reverted to later.

The charging time is predetermined by an external clock at pin 16 or by

an internal clock. The internal timer allows three periods to be preset: 30 m; 1 h; and 12 h. Charging during the 30 m and 1 h periods takes place at full current. During the 12 h period, the charging current is pulsed in a similar manner as in trickle charging but the 100 ms

pulses now occur every 1.2 s. Effectively, therefore, the battery is charged at  $1/12$  of the full current.

The charging current may be altered with  $P_2$ . This preset varies the voltage across it, which changes the duty factor of an internal pulse-width modulator (PWM). This modulator, which drives the charging output, is clocked at a rate of 200 Hz. In this manner, the effective value of the charging current is made continuously variable.

To obviate any possible damage to the battery during fast charging, the processor has an internal failure circuit and two protection circuits: one against overheating of the battery and the other against overcharging the battery.

The battery temperature is monitored via an NTC (negative temperature coefficient) resistor,  $R_8$ , and pin 5. If the level at that pin drops below 0.525 V (equivalent to 40 °C), an error is registered. The NTC sensor must, of course, be in close contact with the battery. Should  $R_8$  itself, or its connections, become defect, the voltage at pin 5 will rise: when this exceeds 2.95 V, an error is signalled.

If the charging voltage per cell rises above 1.6 V, the potential at pin 4 will exceed 0.525 V, whereupon an error is signalled. The voltage of 0.525 V is obtained via a precise potential divider,  $R_{14}$ - $R_{15}$ - $R_{16}$ . The voltage across the

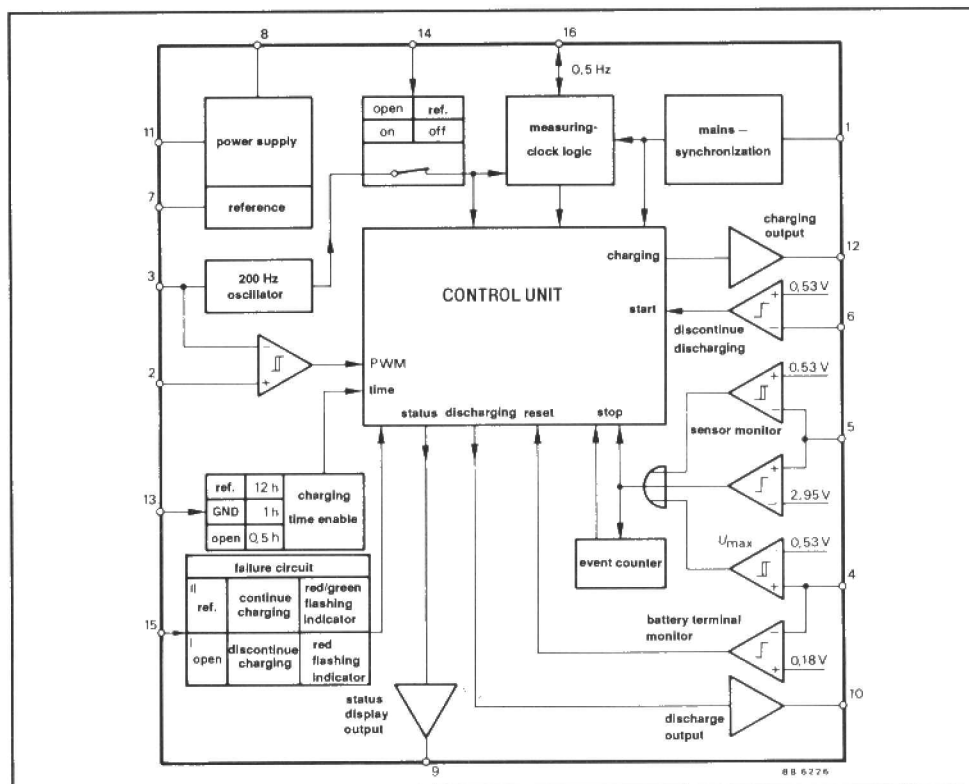


Fig. 1. Block diagram of Telefunken's Type U2400B battery charging processor.

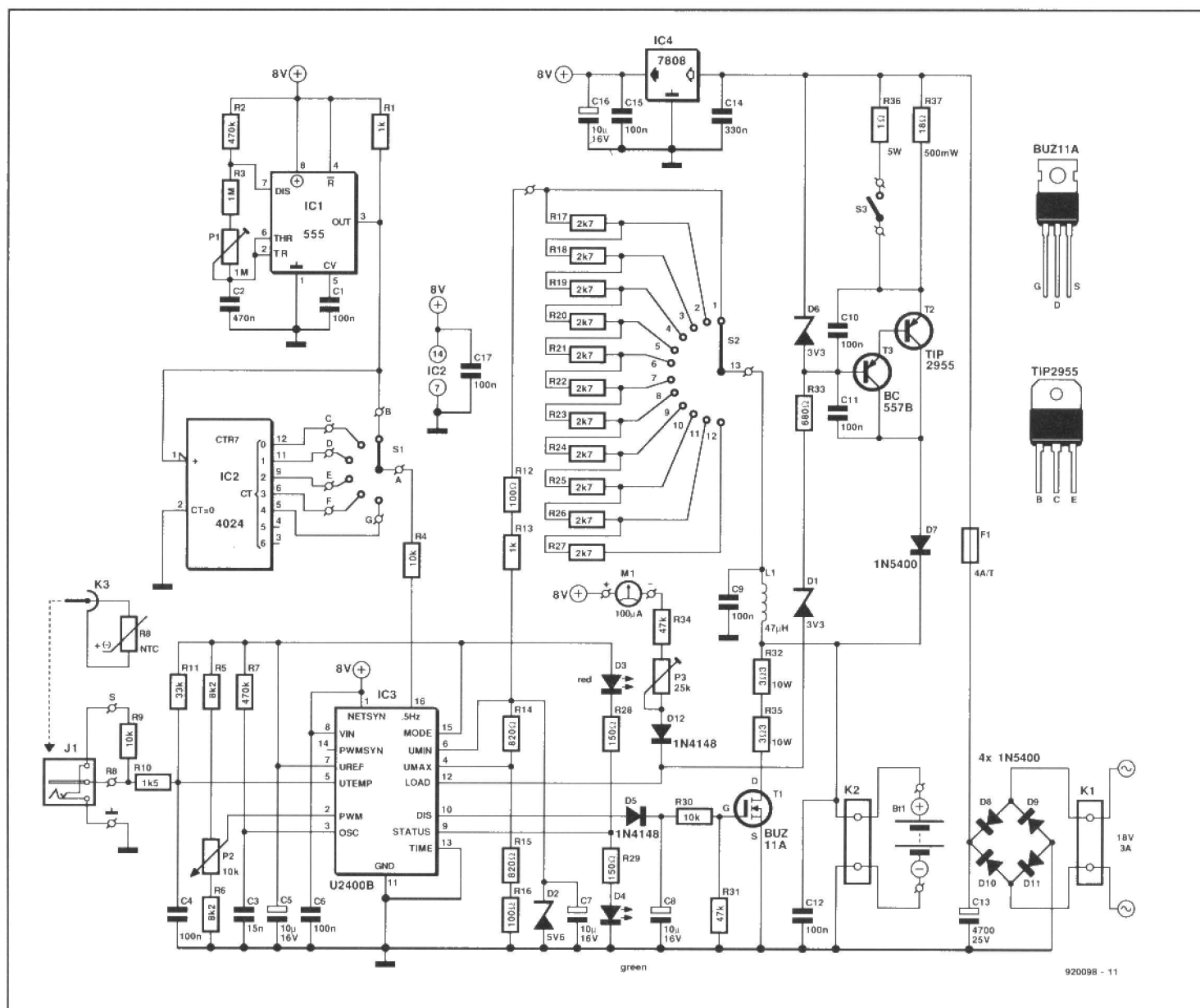


Fig. 2. Circuit diagram of the U2400B NiCd battery charger.

divider is held steady by zener diode  $D_2$ .

After an error has been signalled to the failure circuit, the processor stops the charging as long as the error persists. Once the error has been removed, charging is recommenced. If, however, a second error is registered, further action depends on the level at pin 15. If that pin is open, trickle-charging is substituted. In that case,  $D_3$  (red) lights. If, however, the reference voltage (3 V, pin 7) is connected to pin 15, as in the present circuit,  $D_3$  and  $D_4$  flash alternately. When the error is removed, continued flashing indicates that the remainder of the charging can be undertaken.

When the supply voltage is switched on, the U2400B is enabled; if no battery is connected, the red LED will light. When a battery is then connected, the potential at pin 4 will be 200–525 mV, provided that the voltage per cell is not lower than 0.6 V. After about 2 s

(during which time the LEDs do not light), the processor will become fully operational. What happens if the cell voltage is below 0.6 V will be discussed later.

During the discharge phase, the red LED flashes: when charging is in progress, the green LED flashes. When the battery is being trickle-charged, the green LED lights continuously.

### Circuit description

The mains transformer for the power supply is not shown in Fig. 2. It provides a secondary voltage of 18 V at a load current of 3 A. After the secondary voltage has been rectified and filtered, it is lowered to 8 V by regulator IC<sub>4</sub>, and used to drive control circuits IC<sub>1</sub>–IC<sub>3</sub> and the ammeter. Since the secondary voltage may be as high as 30 V under no-load conditions, IC<sub>4</sub> is mounted on a small heat sink. Also, since the potential at pin 12 of IC<sub>3</sub> must not ex-

ceed 27 V,  $D_1$  is inserted in the line to the charging circuit.

The charging circuit, based on  $T_2$  and  $T_3$ , is a simple constant-current source. When the level at pin 12 of IC<sub>3</sub> is low,  $D_6$  is on, resulting in a constant voltage at the base of  $T_3$ . Since the potential drop across the base-emitter junctions of Darlington pair  $T_2$  and  $T_3$  is a steady 1.5 V, the voltage across  $R_{36}$  and  $R_{37}$  is a constant 1.8 V. When  $S_3$  is open, the current through the transistors, that is, the charging current, is thus 100 mA. When  $S_3$  is closed, the emitter resistors are in parallel, so that the charging current is 2 A. Diode  $D_7$  prevents the battery discharging when the charger is switched off. Since the dissipation of  $T_2$  may be as high as 35 W (one cell and a charging current of 2 A), it is mounted on a suitable heat sink.

Since the discharge output is also controlled by the PWM, the positive pulses at pin 10 of IC<sub>3</sub> charge capaci-

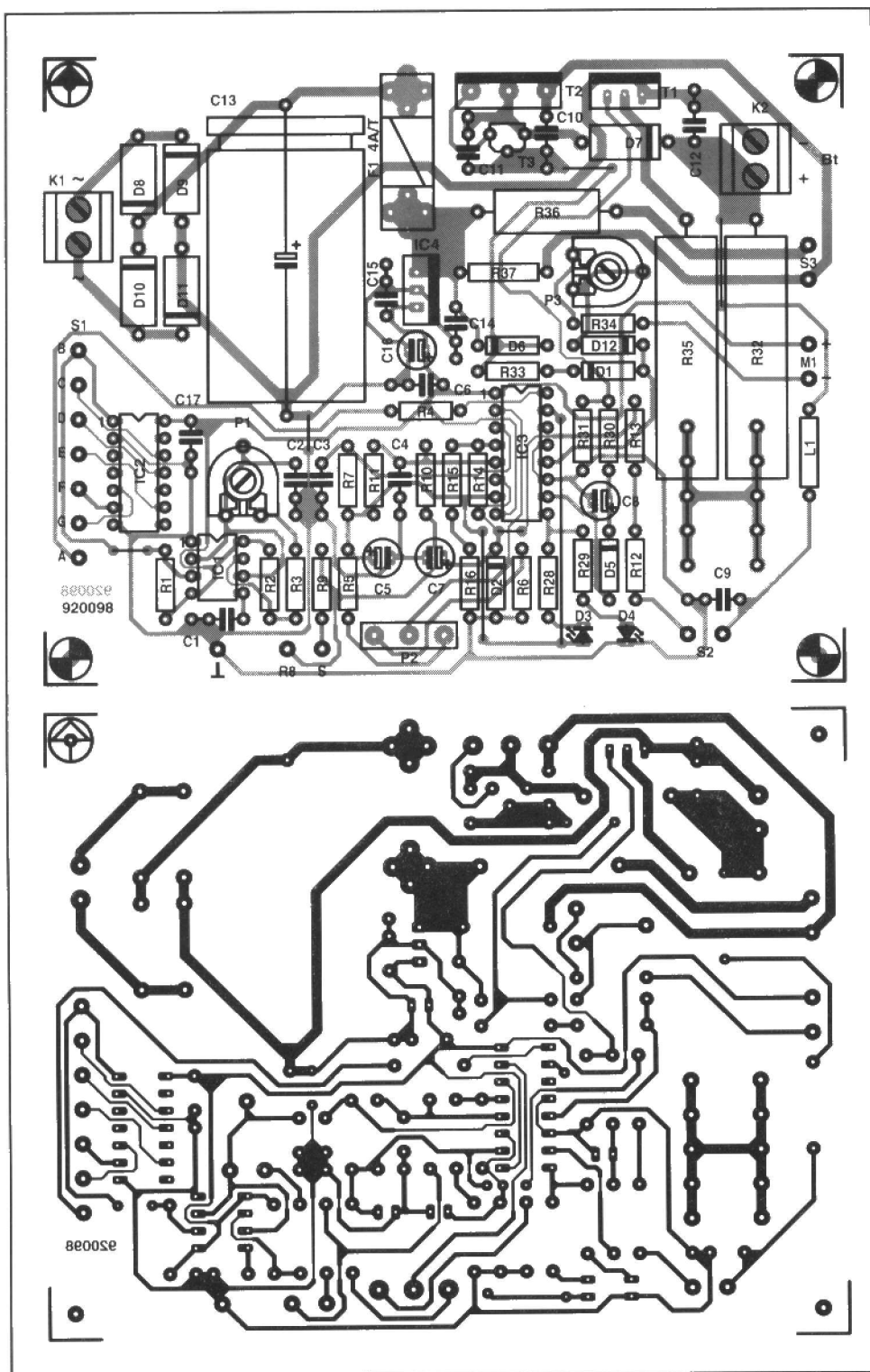


Fig. 3. Printed-circuit board for the U2400B NiCd battery charger.

tor  $C_8$ . The resulting voltage across this capacitor switches on  $T_1$ . This is always providing that a current of  $>0$  A has been preset. Since  $T_1$  is a power MOSFET, which has a very low on resistance, the discharge load is formed almost entirely by  $R_{32}$  and  $R_{35}$ . Although the discharge current depends on the battery voltage,  $IC_3$  ensures that all types of batteries are discharged correctly.

Twelve-way rotary switch  $S_2$  ensures that the overvoltage monitoring is adapted to the number of cells contained in the battery. Zener diode  $D_2$  protects

pins 4 and 6 of  $IC_3$  from too high a voltage if, for example,  $S_2$  is set to the position for a single cell and a 12-cell battery is connected to the charging terminals. The potential at either of these pins must not exceed 6 V. This switch is a make-before-break type to minimize voltage surges during switching.

Rotary switch  $S_1$  links the U2400B to the external clock, an astable multivibrator (AMV) based on the well-known Type NE555 timer IC. The clock rate is set to 1 Hz, that is, a period of 1 s, with  $P_1$  (this is, by the way, the

## PARTS LIST

### Resistors:

$R_1, R_{13} = 1 \text{ k}\Omega$   
 $R_2, R_7 = 470 \text{ k}\Omega$   
 $R_3 = 1 \text{ M}\Omega$   
 $R_4, R_9, R_{30} = 10 \text{ k}\Omega$   
 $R_5, R_6 = 8.2 \text{ k}\Omega$   
 $R_8 = 10 \text{ k}\Omega$ , NTC  
 $R_{10} = 1.5 \text{ k}\Omega$   
 $R_{11} = 33 \text{ k}\Omega$   
 $R_{12}, R_{16} = 100 \Omega$   
 $R_{14}, R_{15} = 820 \Omega$   
 $R_{17}-R_{27} = 12.7 \text{ k}\Omega$   
 $R_{28}, R_{29} = 150 \Omega$   
 $R_{31}, R_{34} = 47 \text{ k}\Omega$   
 $R_{32}, R_{35} = 3.3 \Omega$ , 9 W  
 $R_{33} = 680 \Omega$   
 $R_{36} = 1 \Omega$ , 5 W  
 $R_{37} = 18 \Omega$ , 0.5 W  
 $P_1 = 1 \text{ M}\Omega$  preset  
 $P_2$  = potentiometer,  $10 \text{ k}\Omega$ , linear  
 $P_3 = 25 \text{ k}\Omega$  preset

### Capacitors:

$C_1, C_4, C_6, C_9-C_{12}, C_{15}, C_{17} = 100 \text{ nF}$   
 $C_2 = 470 \text{ nF}$   
 $C_3 = 15 \text{ nF}$   
 $C_5, C_7, C_8, C_{16} = 10 \mu\text{F}$ , 16 V, radial  
 $C_{13} = 4700 \mu\text{F}$ , 25 V  
 $C_{14} = 330 \text{ nF}$

### Inductors:

$L_1 = 47 \mu\text{H}$   
 $Tr_1$  (not shown) = mains transformer, 18 V, 3 A secondary

### Semiconductors:

$D_1, D_6$  = zener diode 3.3 V, 400 mW  
 $D_2$  = zener diode 5.6 V, 400 mW  
 $D_3$  = LED, 3mm, red  
 $D_4$  = LED, 3 mm, green  
 $D_5, D_{12} = 1N4148$   
 $D_7-D_{11} = 1N5400$   
 $T_1 = BUZ11A$   
 $T_2 = TIP2955$   
 $T_3 = BC557B$   
 $IC_1 = NE555$   
 $IC_2 = 4024$   
 $IC_3 = U2400B$   
 $IC_4 = 7808$

### Miscellaneous:

$F_1$  = fuse, 4 A, with holder for PCB  
 $K_1, K_2$  = 2-way terminal block, pitch 5 mm  
 $M_1$  = moving coil meter,  $100 \mu\text{A}$   
 $S_1$  = 1-pole, 6-position rotary switch  
 $S_2$  = 1-pole, 12-position rotat switch  
 $S_3$  = single-pole on-off switch  
Heat sink Type SK81 ( $1.5 \text{ K W}^{-1}$ )  
PCB Type 920098: see page 70.

only calibration required). This switch is a break-before-make type to prevent short-circuiting of IC outputs. The outputs of scaler  $IC_2$  provide six frequencies, corresponding to six different charging times—see Fig. 5.

The voltage set with  $P_2$  controls the PWM and thus the charging current. The voltage range is extended by  $R_6$  and  $R_9$ , so that at the two extreme settings of  $P_2$  a narrow 'dead zone' exists. This ensures that the charging current can be set correctly between zero and maximum.

The NTC sensor is connected to the



charger via a switched jack socket,  $J_1$ . In this way, the resistor may be removed when a sealed battery is being charged. Since the sensor cannot come into close thermal contact with such a battery, temperature monitoring is impossible and it is, therefore, better removed. Resistor  $R_9$  then simulates a 'cool' sensor, whereupon charging can commence.

The many 100 nF capacitors and inductor  $L_1$  serve to decouple any incoming RF radiation and spurious voltage peaks on the mains supply.

## Construction

The charger is best built on the PCB shown in Fig. 3. This board has been designed so that the operating controls,  $S_1$ – $S_3$  and the LEDs are mounted on one side and the power transistors on the other side. The power transistors must be fixed with the use of insulating washers and plenty of heat conducting paste. A heat sink rated at  $1.5 \text{ KW}^{-1}$  is then fitted behind the transistors (again with plenty of heat conducting paste)—see Fig. 4. It is also possible to fit the power transistor to the inside rear panel of the enclosure and the heat sink to the outside (again, use plenty of heat conducting paste and insulating washers and bushes). If the heat sink is fitted inside the enclosure, make sure that there is adequate ventilation (drill a number of small holes in the top panel or fit a small extractor fan).

Commence the populating of the board with fitting the wire links. Load resistors must be mounted at least 10 mm ( $\frac{7}{16}$  in) above the board's surface. Resistors  $R_{17}$ – $R_{27}$  must be soldered direct to the relevant terminals of  $S_2$ —see Fig. 2. Only two wires then link the switch to the board.

Preset  $P_1$  is adjusted by using either an oscilloscope or a frequency counter between terminal B of  $S_1$  and earth.

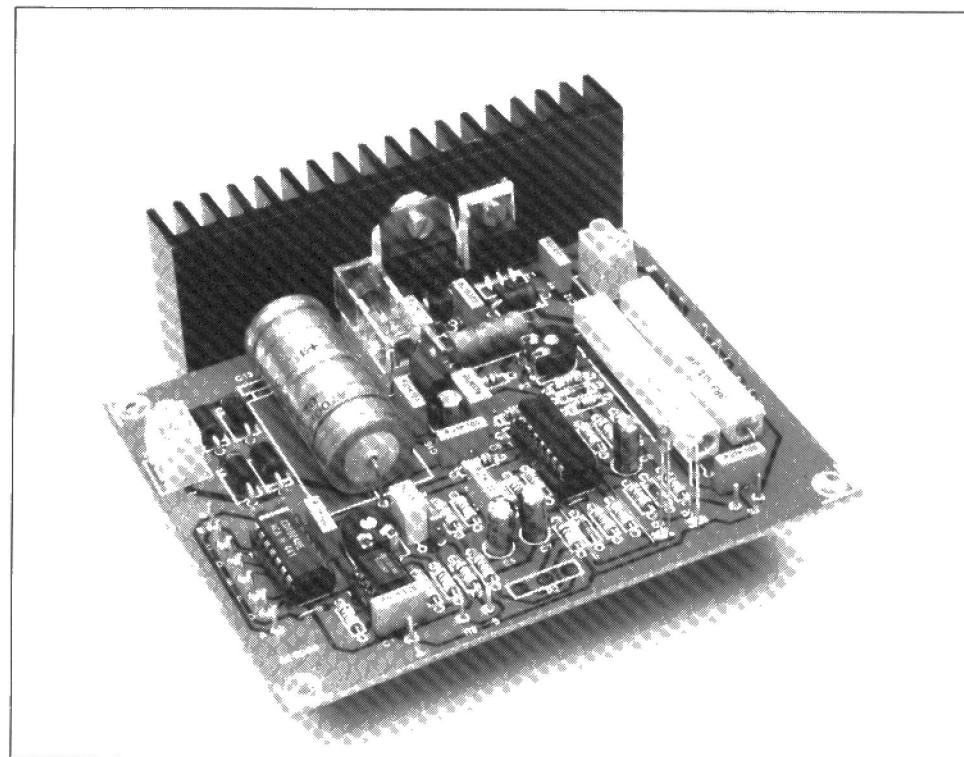


Fig. 4. The completed printed-circuit board showing the position of the heat sink.

In the first case, set  $P_1$  to obtain a period of 1 s; in the second case, adjust it to obtain a frequency of 1.0 Hz.

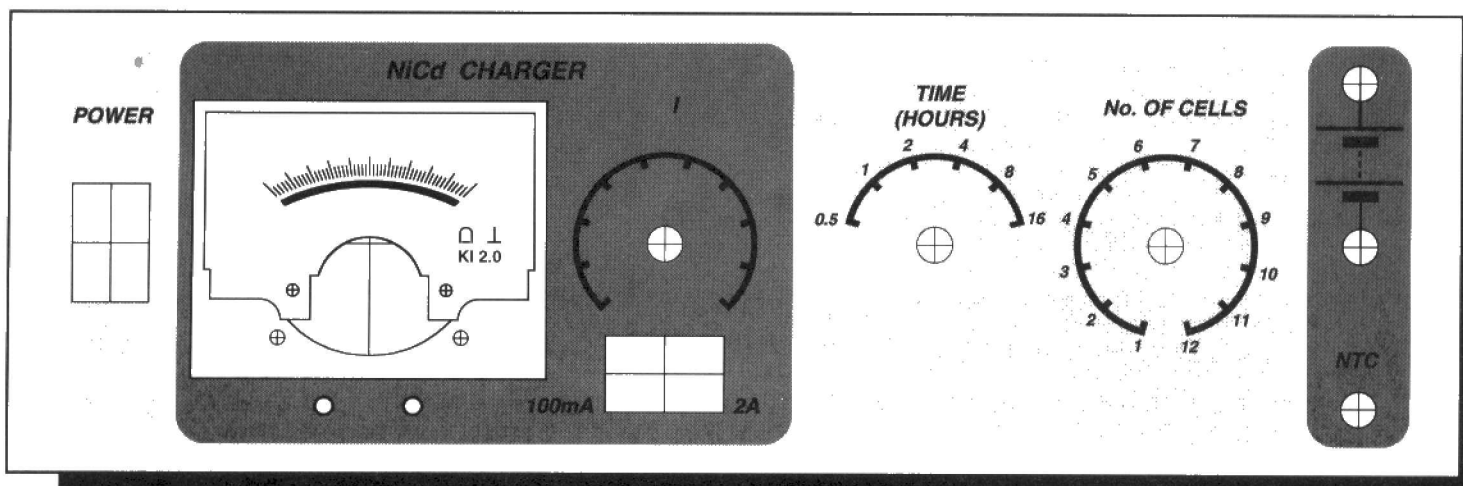
If neither of these instruments is available, set  $P_1$  to the centre of its travel and  $S_1$  to position 30 min (B). Select the number of cells ( $S_2$ ) and the required charging current ( $S_3$  and  $P_2$ ). Switch on the mains, whereupon the red LED should light (do not insert the NTC sensor). Connect a battery to the charging terminals, when after two seconds the red LED should begin to flash, indicating that discharging has commenced. Shortly thereafter, charging begins and the green LED starts flashing. Note the time during which the LED continues to flash. Any deviation from 30 min should be corrected

with  $P_1$ . This method may require the calibration to be repeated several times before the length of the period is right.

The ammeter is calibrated simply by measuring the voltage across  $R_{37}$ , preferably with a standard analogue voltmeter, setting  $S_3$  to position 100 mA, and adjusting  $P_2$  for maximum current. When the voltage across  $R_{37}$  is 1.8 V, adjust  $P_3$  for full-scale deflection (FSD) of the meter. This calibration should, of course, be carried out in the charging mode.

## Hints and modifications

Before connecting a battery to the charger, make sure that the switches are set as required and that the red LED lights



920098 - F

Fig. 5. A front panel foil for the charger (here shown reduced to 75%) is available ready made – see page 70.

when the charger is switched on. If it does not, it may help to switch the mains off and then on again. These precautions are necessary in view of the fact that it happens once in a blue moon that undefined levels occur at the IC inputs when the switch is turned.

It is advisable to overcharge the battery by about 20% as a matter of course. That is, charge a 500 mAh battery as if it were a 600 mAh type. Divide this capacity by the desired charging time (in h) to arrive at the charging current to be set. Say, for example, that in the case of the 500 mAh battery the charging time should be 30 min. A quick calculation gives a charging current of 1.2 A. If fast charging is contemplated, make sure that the battery is designed to cope with it.

The charger is not able to register that a battery has been connected to the charging terminals when the voltage per cell has dropped below 0.6 V. Although such a battery can be given a quick (<1 m) boost by connecting it to a mains adaptor with current limiting, it is far better to use the additional circuit shown in Fig. 6 to cope with flat batteries. Spring-loaded switch  $S_4$  connects a 10 k $\Omega$  resistor,  $R_{38}$ , between pins 4 and 7 of IC<sub>3</sub>, thereby 'tricking' the circuit into starting charg-

ing. These additional components are best connected into the circuit at junction  $R_{14}$ - $R_{15}$  and the +ve terminal of  $C_5$ . To prevent accidental operation of the switch, it is best to use a flush (set-in) type or to fit it at the rear panel.

It may also prove useful to connect a flush spring-loaded switch,  $S_5$ , across capacitor  $C_7$  with which to end the discharge. When this switch is pressed, charging will commence.

If only small cells or batteries (up to no more than 600 mAh) are to be charged, it may be useful to restrict the peak charging current to 1.2 A. In that case, the rating of the heat sink may be reduced to 2.5 K W<sup>-1</sup>,  $R_{36}$  to 1.8  $\Omega$ , 4 W, and the transformer secondary rating to 1.8 A. The scale of the meter must, of course, also be adapted.

If charging of 10-cell batteries only is foreseen,  $S_2$  may be a 10-way switch,  $R_{26}$  and  $R_{27}$  are not required, and the secondary voltage of  $T_1$  needs to be only 15 V. If only 6-cell batteries are to be charged,  $S_2$  may be a six-way type,  $R_{22}$  to  $R_{27}$  may be omitted, and the secondary transformer voltage needs to be 10-12 V only. In both cases, smaller heat sinks will suffice. ■

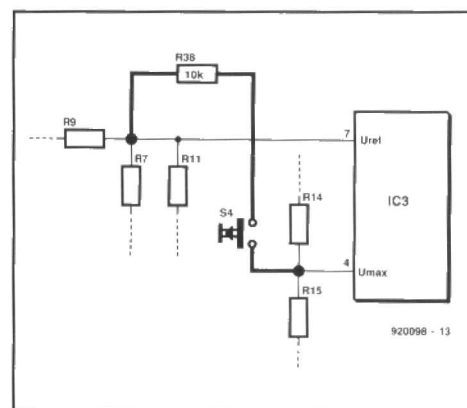


Fig. 6. If charging flat batteries is a frequent requirement, a simple switch and a 10 k $\Omega$  resistor are a worthwhile extra.

## Specialists in Control

Z80/6502/6809	Minimal System controllers 16 I/O	\$99
Z80/6502/6809	"Systems" RGB video, RS232, 16I/O Floppy Disk & monitor EPROM.	From \$108
68000-8	"Leo 68" includes:- 16char Lcd, Serial Controller, Real time Clock, 40 I/O,	\$270
64180 Micro	4 RS232 channels, 20 I/O, 32K RAM Monitor EPROM.	\$270
Serial 6502	6 RS232 channels, 8K RAM, Monitor EPROM.	From \$180
Parallel 6502	64 I/O lines 8K RAM Monitor EPROM.	From \$180
Midi 6501AQ	30 I/O, RS232/MIDI channel, 32 char LCD display, 32K RAM, Monitor Eprom	\$170
Z8 Micro	BASIC Language, 35 I/O, RS232/MIDI 32K RAM, 32 char LCD display.	\$260
8052A Micro	BASIC Language, 30 I/O, RS232, 32K Ram, Eprom Programmer.	\$225
6501AQ Step	3 axis stepper controller, 6501 micro, RS232, BASIC like control language.	\$270
LCD/LED Disp	4 & 8 character display modules controlled by serial communication.	From \$54
BACKCHAT	Record/Playback Module for high Quality speech messages.	\$54
DEL109 PSU	Triple Rail Power Supply +5/+12/-12V	\$45
ERASER	Eprom Eraser with or Without Timer	\$90
EMULATOR	Eprom Emulator 2764-27256 Types RS232 communications.	\$225
CROSS ASM	PC based CrossAssembler for most types of microprocessor.	\$160

Please Ask for our **Free** Catalogue, All Prices exclude Postage.

Tel+44 353 88325

**J.P. Distribution** Fax +44 353 88455

○The Old School, Prickwillow, Ely, Cambs CB7 4UN England○

## SHERWOOD Data Systems

... The single board computer people

The Archer



2 serial ports  
4 memory slots  
Watchdog timer

4 counter timers  
Battery Backup

32 digital I/O lines  
Expansion bus  
Powerfail interrupt

### Options

Debug Monitor  
Option Switches

Desk top case  
ROMable basic

On board mains psu  
Various daughter cards

Sherwood Data Systems Ltd.,

Tel: 0494 464264

## A possible mechanism for the effects of electromagnetic fields on biological cells

By Dr K.A. McLauchlan, F.R.S.

**It is widely believed that electromagnetic fields can affect biological systems, including man, although the evidence remains equivocal. Quite apart from the difficulty in establishing a causal relationship, the research field has been held up by a lack of a general mechanism to rationalize why such effects might be expected. Yet, at the same time, it is well established that even very small fields can affect chemical reactions in a way that is completely understood.**

**Here, we attempt to explain how, to suggest some possible relevances to the biological situation, and to predict what effects might be looked for to confirm the relevance of the mechanism there. This may help to target epidemiological studies on human systems so as to establish the perceived effects.**

People are continuously exposed to electromagnetic radiation from their environment, which arises from the normal electric and electronic paraphernalia of modern living, and in various manufacturing processes. It has been believed for some time that it may produce harmful effects, and recommended levels of exposure have been defined in most developed countries. Such evidence as exists comes from both epidemiological studies and from direct biological experiments. The seminal example of the former is the investigation of the incidence of childhood leukaemia in Boulder, Colorado, by Drs Leeper and Wertheimer. They showed that the incidence, apparently, correlates with the proximity of overhead power lines to an alarming degree, although the strengths of the magnetic fields they measured were not substantially greater than that caused by the earth. Subsequent, and continuing, epidemiological studies appeared to confirm an effect, and have led to the re-siting of transmission lines away from sensitive regions of human habitation in some places, and to the detailed planning of their routes in others. Nevertheless, a recent working party of the Institute of Electrical Engineers concluded that epidemiological studies were not likely to confirm the effects, owing to the difficulty in excluding other possible environmental causes.

Many direct experiments on intact biological systems have been described, some with a disproportionate effect on this research field. Thus, Professor Loboff and his colleagues in the United States have published a series of articles which purport to show that very small fields varying at low audio frequencies have direct biological or biochemical effects in many systems. A typical example is the inclusion of  $^{45}\text{Ca}$

in human lymphocytes in which they reported a resonance effect, of greater or less incorporation of the radionuclide, depending on the field strength, at 14.27 Hz. In this, and the other results from Professor Loboff's group, the resonance frequency appeared to correlate with the cyclotron resonance frequency of the isotope within the field, and this formed the basis of a general theory. Although this is un-physical, it was widely accepted.

More recently, Dr Lednev from Puschino, Russia, reported that the phosphorylation of myosin involving a calcium-binding protein was enhanced when the reaction system was simultaneously exposed to the earth's field and a field fluctuating at 16 Hz. However, neither do sets of these experiments seem to have been satisfactorily reproduced in other laboratories; nor have the multitude performed on intact specimens. This is despite the expenditure of large funds in a world-wide experimental effort.

Some experiments are still accepted as significant, however, notably the demonstration by Dr Reba Goodman at Columbia that the production of messenger RNA from leukaemic cells is significantly enhanced by application of a 100 Hz field.

Recent reports from the National Radiological Protection Board indicate that it remains unconvinced by the epidemiological studies and sceptical that cellular DNA is damaged directly by exposure to electromagnetic fields.

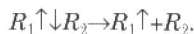
A limiting feature of demonstrating that biological field effects do exist is that there is no accepted theory for them, which makes specific scientific tests nigh impossible. Furthermore, studies have not been made at the molecular level, where biological chemistry occurs. However, it is known that some chemical reactions—those that

involve free radicals—are affected by applied magnetic fields in completely understood ways. What is more, the importance of free radical processes within the body is becoming more and more apparent. It is consequently possible to suggest a mechanism, capable of experimental test, via which fields might have a direct effect in the biological situation. It must be stressed that the link between the chemistry and the biology has not yet been demonstrated. It is to the chemical mechanism that we now turn.

### Electrons and their spin in chemistry

The formation of chemical bonds involves the sharing of pairs of electrons between atoms, or common groups of atoms known as radicals (e.g., the methyl radical  $\text{CH}_3$ ). Electrons possess the property of spin angular momentum, and relative to each other the resolved components of this (the 'spin') may be either parallel (a 'triplet,  $T$ , state') or antiparallel (the 'singlet,  $S$ , state'). It has been known for many years that the electrons in the bond have antiparallel spins or, to put it in another way, electrons must have antiparallel spins to form bonds. Normal molecules therefore exist in  $S$  states. When a molecule dissociates in a chemical reaction, one electron is taken by each radical and there results a pair of free radicals. These are highly reactive since each contains an unpaired electron. Only recently has it been realized that spin is conserved in this reaction, and that dissociation of a singlet molecule results in the production of a singlet 'radical pair'; that is, at the time that the pair is formed, the relative electron spins are defined:





This is one of the two crucial features that underlie the effects of magnetic fields on chemical reactions. Since the free radicals are formed very close together in the solution, and they have the correct spin orientation for reaction, we should expect the bond to reform very rapidly, and no free radicals to escape from the initial region in which they are created. Free radical chemistry would exist only if the radicals reacted extremely rapidly with their immediate environment to prevent their recombination. This is, however, against experience, for we know that free radicals are present in many reactions where these competing reactions do not occur. We conclude that a mechanism must exist by which the reactive *S* state of the radical pair changes rapidly into the un-reactive *T* one, so that the overall process can be represented as:

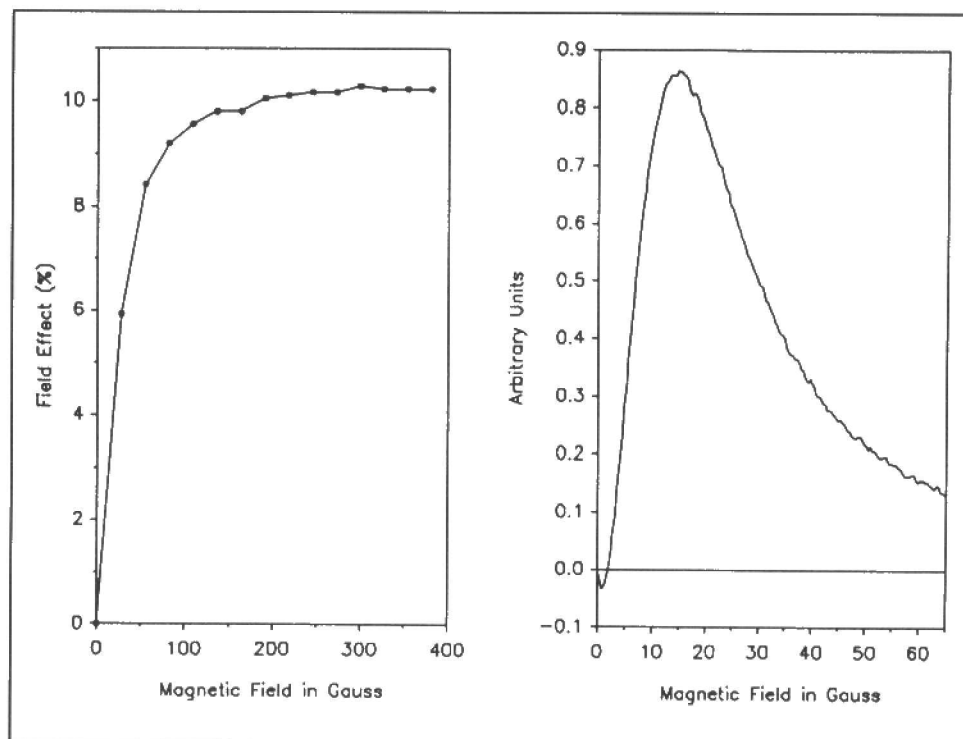


The *S* ↔ *T* conversion is itself reversible, but molecular diffusion in solution normally suffices to separate the radicals before they re-attain the *S* state and are able to react.

There are, in fact, three *T* states whose energies become unequal when a magnetic field is applied to the system. They are labelled  $T_0$ ,  $T_{+1}$ , and  $T_{-1}$ , where the subscript represents the resultant spin (each electron has a value of 1/2) in the direction of the field. Since the electron has an electric charge besides its spin, it possesses a magnetic moment. The implication is that two of these triplet spin states of the radical pair are magnetic, whilst the other is not. This is the next crucial feature underlying the normal effects of magnetic fields in chemistry.

## How conversion between the singlet and triplet states occurs

The mechanism for the conversion between the *S* and *T* states of a radical pair consisting of two organic radicals is itself magnetic, and in applied magnetic fields below 10 000 gauss or so in strength is dominated by the hyperfine interactions between the electrons and nearby magnetic nuclei in the radicals. These are normally protons. In very low fields, including the earth's field, this interaction is capable of changing the *S* radical pairs into all three types of un-reactive *T* state, and as a consequence the overall reaction probability falls (after the conversion has occurred) to one quarter of its original value. In the biological context, this may be a bad thing, for it implies that a greater concentration of possibly damaging radicals escapes into the surroundings from where the radical pair is formed. Hyperfine interactions are, however, very weak and they can only cause interchange between states which have energies that are very close. Now, since the  $T_{+1}$  and  $T_{-1}$  states are



The variation in light intensity is shown for the reaction studied following laser excitation of pyrene over a field range from zero to about 400 gauss.

magnetic, their energies are changed when an external field is applied whereas those of *S* and  $T_0$  states are not. Once their energies differ from that of the *S* state by more than the hyperfine field, the states become inaccessible, and now this can turn into only one un-reactive *T* state:  $T_0$ . The effect of the field is, therefore, to double the reaction probability, and to lessen the number of potentially dangerous free radicals escaping the initial recombination process. This process is complete in fields of about 100 gauss, and no further field effects occur until very high fields (>10 000 gauss) are reached, when other mechanisms dominate.

The process whereby fields affect reactions is of an entirely kinetic nature and this simple description has included no discussion of the rate of the *S* ↔ *T* mixing process. It is not instantaneous, and the actual magnitudes of the field effects observed consequently depend intimately on the period available for interconversion; this implies that they are increased in viscous media, in micelles, in microemulsions, at surfaces, and so on.

Most environmental fields are very low indeed, and unfortunately it happens that there exists a further mechanism, demonstrable within the laboratory, via which the effect of the field is now harmful, in increasing the free radical concentration, rather than beneficial. Its origin is also in the hyperfine interaction, but it is complex and involves the conservation laws of angular momentum within and outside applied magnetic fields. These have the effect of restricting the mixing of certain hyperfine substates of the radical pairs in zero field but allowing them between all

the *T* states in slightly higher ones. This effect starts at the lowest field strengths with possible environmental biological relevance. It implies that as the field is increased from zero, the recombination probability of the radical initially decreases before the effect discussed above takes over to increase it. There is consequently a maximum effect which occurs at fields less than 10 gauss for most chemical reactions.

Once again, the actual magnitude of the effect observed in this low-field region depends upon the diffusion conditions within the reaction system, but it is typically a few percent. This may seem small, but it is not necessarily negligible in the biological situation, as is discussed below.

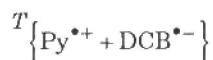
## Experimental results

A simple system for demonstrating that magnetic fields really do affect chemical reactions involving free radicals is one in which a product is formed by their recombination which fluoresces. The effect of the field is observed directly in the variation of the intensity of the emitted light as the applied field is changed. A suitable reaction involves pyrene (Py), excited to a singlet excited state in a light beam and then reacting with dicyanobenzene (DCB). In detail, this reaction occurs through the formation of a singlet exciplex, which is the entity that fluoresces.

In Fig. 1, the variation in light intensity is shown for the reaction studied following laser excitation of pyrene, and with a radical concentration of about  $10^{-7}$  M, over a field range from zero to about 400 gauss. It shows a typical sigmoid dependence, with the reaction probability to form



↓ ↑ magnetic field sensitive stage



the exciplex increasing as the field is increased. This is exactly what is expected as the  $T_{+1}$  levels become decoupled from the  $S$  one with an increasing field. To demonstrate the low-field feature in this system, we use a lower radical concentration ( $10^{-10}$  M) and a more sensitive technique which then displays the derivative of the field-dependence curve. The result is shown in Fig. 2, where the sweep is over the first 65 gauss of Fig. 1 and the feature is seen. This trace goes through zero at about 4 gauss, where the field-dependence curve exhibits a maximum, and then it shows a maximum in the opposite sense as the field is increased further; it returns to zero when the curve shown in Fig. 1 demonstrates its plateau behaviour, although this asymptote is not shown in this figure.

### Relevance to biology

The chemistry and its rationalization are

firmly established, but the jump to biological relevance is at present conjectural. It is known that free radicals are mutagenic, and attack DNA directly. It may be suggested that any increase in the concentration of free radicals in the body is potentially dangerous, and the field, at low strengths, exactly causes this, although at higher values the reverse is true, and the field may be protective. This seems not to have been suggested before. The changes in concentration in this field region are only a few percent, and it might be asked if it is relevant. In the first place, it should be remembered that DNA is a chemical amplifier with a high gain, and, secondly, that the typical time scale of carcinogenic processes is long. In normal healthy people, efficient biochemical pathways exist to remedy the effects of damage to DNA, and the obvious experimental test for the type of mechanism suggested here is to look for field effects in biological systems in which this repair mech-

anism is already working hard, that is, ones already exposed to carcinogens. This experiment may already have been done, for there are several reports of the synergistic effects of fields with carcinogens. Similarly, epidemiological studies should be targeted on those already exposed to chemical hazards. No studies of this type appear to have been reported. What must be realized is that if this mechanism is the source of field effects on humans, the dose response curves are quite different from those of high energy radiation, for example, and are, in fact, represented by the experimental curves shown in the figures.

It is an intriguing thought that the application of magnetic fields at strengths above about 10 mT may provide increased protection from certain carcinogens to man.

Although this article has dealt with static fields, closely related ideas can be used to rationalize the effects of fluctuating ones, and combinations of the two. ■

it's **OK** to use **OKI**

speech synthesis devices in your projects.

**Programming of your voice onto silicon  
is now available.**

**For all your speech synthesis and other  
development requirements call or write to us.**

**HSP Electronics Ltd**

**29 Princes Avenue London N3 2DA**

**Tel: 081 343 4036 Fax: 081 349 1149**

## ADVERTISING IN *Elektor Electronics*

The closing date for copy is five weeks before publication date (four weeks for camera-ready copy).

Colour advertisements should be submitted on film separations. *Elektor Electronics* is published on the third Thursday of the month preceding cover date.

*Elektor Electronics* (Publishing) will not be liable for any loss caused by the failure of any advertisement to appear for any reason, and they do not accept liability for printers' errors, although every care is taken to avoid mistakes.

Copy instructions, artwork and all correspondence pertaining to advertisements should be addressed to

**Elektor Electronics (Publishing)**

**Advertisement Department**

**3 Crescent Terrace**

**CHELTENHAM GL50 3PE**

**England**

**Telephone (0242) 510 760**

**FAX (0242) 226 626**



**IF AN  
ADVERT IS WRONG,  
WHO PUTS IT RIGHT?**

We do. The Advertising Standards Authority ensures advertisements meet with the strict Code of Advertising Practice.

So if you question an advertiser, they have to answer to us.

To find out more about the ASA, please write to  
Advertising Standards Authority,  
Department X, Brook House,  
Torrington Place, London WC1E 7HN.



This space is donated in the interests of high standards in advertisements.

# DX TELEVISION

A two-monthly column by Keith Hamer and Garry Smith

**W**ELCOME to this new two-monthly column in which we will be covering the fascinating hobby of long-distance TV reception, or DX-TV, as it is universally known. The hobby is in many ways analogous to short-wave listening where pleasure is derived from identifying distant sources of transmissions — the more elusive, the greater the satisfaction. Nowadays TV reception from other countries is taken for granted thanks to satellite technology, but it could come as a surprise to learn that TV signals have been crossing international frontiers for many decades.

DX-TV is well established in Europe and in the USA, and it continues to grow steadily in the UK. Unlike their amateur radio counterparts and short-wave listeners, many DX-TV enthusiasts still tend to be isolated with regard to accurate information for keeping up-to-date with changes in TV broadcasting in other countries. We hope that *Elektor Electronics* readers will be sufficiently enthused to write in with details of their reception, and help keep other enthusiasts informed by reporting changes in their local TV services. Many services now display a logo in the corner of the picture — details of your local networks would be appreciated, so that we can pass this information on to other enthusiasts via this regular column.

## Atmospheric influences

The short-wave or medium-wave DX-er will be aware that these bands become active during the hours of darkness. Sunspot activity also plays a part, especially on the higher short-wave frequencies.

A similar situation arises with TV frequencies, although darkness does not improve the chances of reception. A check through the non-local channels on your TV receiver may reveal weaker relay stations which are always present. There will also be many blank channels. This can create the impression that nothing can ever be received on these channels. In reality this is not so.

Given favourable atmospheric conditions, broadcasts from TV transmitters located hundreds or even thousands of kilometres away can be received on these normally vacant channels. Unfortunately, periods of favourable atmospheric conditions on the TV bands are less frequent than at short-wave frequencies,

which means that when conditions are favourable you must make the most of it! A little preliminary knowledge of when and where to tune in is therefore necessary; patience and perseverance are also required, especially when attempting to capture an elusive station.

Under normal reception conditions, the range of a signal emitted from a high-power transmitter is limited to approximately 100 km, although a sea-path can extend this range considerably. Certain atmospheric effects can extend the transmission range even further, albeit only temporarily. There are several types of propagation which can produce signals from distant transmitters. The most spectacular form is sporadic-E ionization, and this is the one which we will describe in this first DX television column.

## Sporadic-E ionization

Long-range TV reception is possible due to reflections within the various layers of the earth's atmosphere, including the E-layer. This particular region is located at approximately 12 km above the surface of the earth. Although it is capable of reflecting short-wave signals, TV signals normally continue through it, and into outer space. However, during the summer months the E-layer becomes highly ionized by the sun, and this can result in signals being reflected, or, more accurately, refracted, back to earth. Reception via sporadic-E can also occur during the winter, but on a much reduced scale.

The unstable nature of the E-layer means that this type of propagation is completely random in terms of direction, distance, duration and signal strength. Reception can last all day, or for only a few minutes, but what surprises many newcomers to the hobby is the high field strength of many of the signals encountered, and the simplicity of the aerial required.

Since the signals are returned to earth, a skip distance is involved which is typically 1500 km. Occasionally longer range reception is possible from the Middle East, Africa and North America, but transmitters closer than 300 km are seldom received via this mode of propagation.

Sporadic-E ionization affects TV channels in the VHF bands between approximately 40 and 100 MHz. In Europe, this means that distant signals on the Band I

channels E2, E3 and E4 can be received in addition to the channels of Eastern Europe and Italy. The FM radio band can also become highly active.

## Tuning in

Unfortunately in the United Kingdom, the budding DX-er will encounter something of a technical obstacle when it comes to sporadic-E reception. This is because TV broadcasting is limited to UHF frequencies only, and as a consequence receivers rarely have a VHF tuner fitted. A few imported models have full VHF and UHF coverage, but these tend to be the exception rather than the rule. In such cases, the VHF tuning scales will be inscribed with channels 2-4 (Band I) and 5-12 (Band III), although this is still no guarantee that a VHF tuner is actually fitted. A frequency up-converter can be used to translate incoming UHF frequencies to a similar spectrum at UHF, but in practice these are only suitable for strong signals.

A special converter system for DX-TV, known as the D-100, has been available for a number of years. Using double conversion techniques, the converter system makes use of a TV receiver which functions as a second IF — the converter simply plugs into the HF aerial socket of a standard receiver. Dial tuning provides VHF and UHF coverage, and the IF vision bandwidth can be progressively reduced to enable weaker signals to be enhanced with the added improvement in selectivity. The unit can be connected to an FM radio to resolve any TV sound carrier even when a reduced vision IF bandwidth is selected. Automatic band-scan is a recently introduced option which allows the TV band to be previewed when reception is imminent, thus freeing the DX-er from constant manual searching.

## Aerials for sporadic-E reception

A simple aerial known as a 'dipole' can be used with an overall length of 2.6 metres. Larger aerials featuring a reflector and directors can be used if space permits — these will be more directional and provide increased gain when attempting to receive weaker signals. Band I aerials of this type are normally widely available outside the UK where this band may be used for local broadcasts. In the UK, the DX-er either has to resort to DIY construction, or purchase one from a specialized supplier.

The height of the aerial is not too important because sporadic-E signals arrive at a slight angle. However, a minimum height of 5 metres is recommended.

If a multi-element array is used, some method of rotation is advisable so that the aerial can be positioned for maxi-



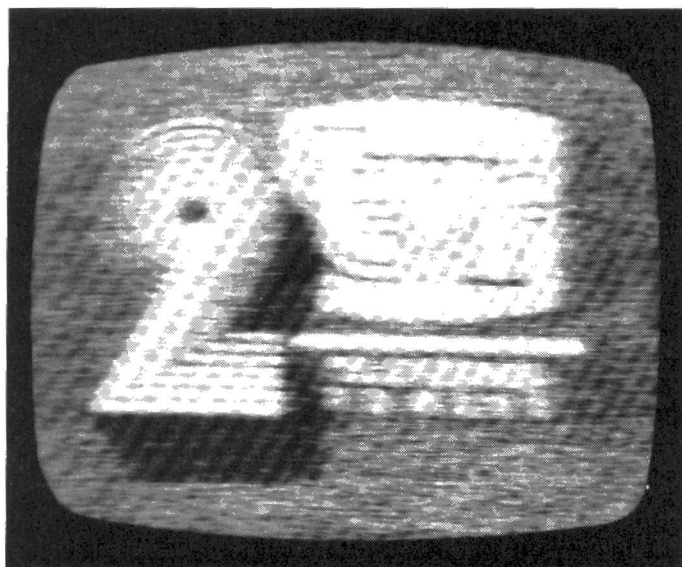


Fig. 1. Rumanian identification caption for their second network, received in Derby via sporadic-E on channel R2.

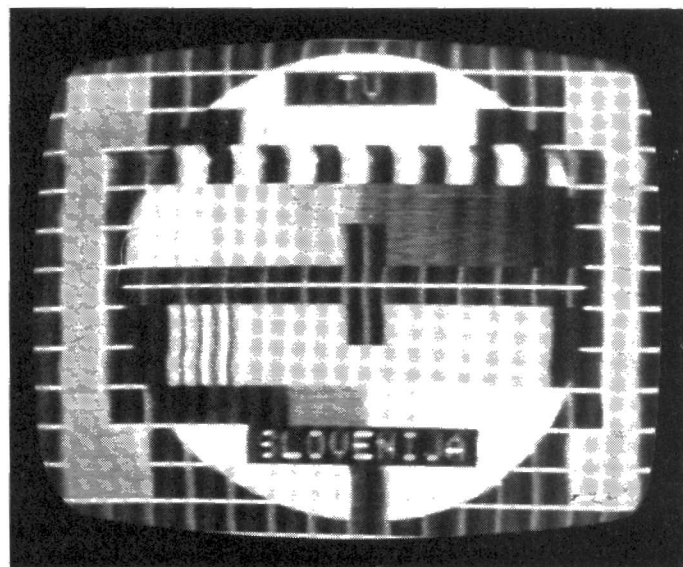


Fig. 2. Slovenian test card received from the 'Kum' transmitter on channel E3.

mum signal. A manually rotatable system is often easy to arrange, although an electric rotator is more convenient because it allows the operator to monitor the screen for best results.

It is advisable to use separate downleads from a multi-aerial installation rather than using a combiner unit at mast-head, feeding a single cable. This is because a combiner introduces a signal loss, which may not be noticeable on local-strength signals, but will certainly be apparent on weak ones. The aim is to preserve as much of the collected signal as possible.

## Be patient

Regularly check Band I channels for signs of unusual activity including patterning from other transmissions in the band such as OIRT FM radio from Eastern Europe, or even cordless telephone carriers from distant countries. Don't forget that, because of the unpredictable nature of sporadic-E propagation, the band may be dead one minute, and choc-a-bloc with signals the next. So keep trying. The D-100 converter with band-scan is invaluable in this respect as it saves having to constantly twiddle with the tuning controls.

## The 1992 sporadic-E season

Reception proved extremely rewarding last summer with signals encountered almost daily. June was the most productive month, but August was relatively quiet. Broadcasts from the new Baltic states have aroused much interest among DXers, but the lack of updated regional logos on the test card has caused a few problems with identification.

One of the highlights in the UK was a sustained transatlantic opening toward

midnight on June 2nd which produced several French and English-language Canadian stations on FCC channels A2, A3 and A4. In the Netherlands and Germany, a number of Arabic countries were resolved during June. These have subsequently been identified from weather maps and news programmes originating in Jordan, Syria, Iran and Egypt.

Andre Gillé in France received the Rumanian test card (TVR Bucuresti) in glorious colour on channel R4 (85.25 MHz) during early June. The picture was remarkably clear and free of interference despite the channel being close to the FM radio band.

Marc Vissers in Belgium logged Tunisia on channel E4 at the end of May, with programmes accompanied by Arabic texts and a logo in the lower right of the screen.

Commenting on a successful season, Marc adds that MRT Pelister (Macedonia), also on E4, and TVM Kisinov (Moldova) on R3 have been identified more times this year than last. Moldova often carries the identification 'tvm' in the lower right hand corner, almost out of screen.

## Service information

**Czechoslovakia:** a change from SECAM to PAL colour is underway, and test transmissions have already been received using the new standard. The 6.5-MHz sound spacing will be retained for the foreseeable future.

**Portugal:** the current identification caption is 'RTC', and the logo 'C1' appears in the corner of the picture.

**Netherlands:** the identification 'NOZEMA' has been added to the top of the PM5544 test card with the appropri-

ate service below (NEDERLAND 1, etc.).

**Norway:** the transmitter name has been deleted from the test card this summer, and has been replaced by 'TELEVERKET' with a superimposed message relating to a change of an emergency telephone number over its lower half.

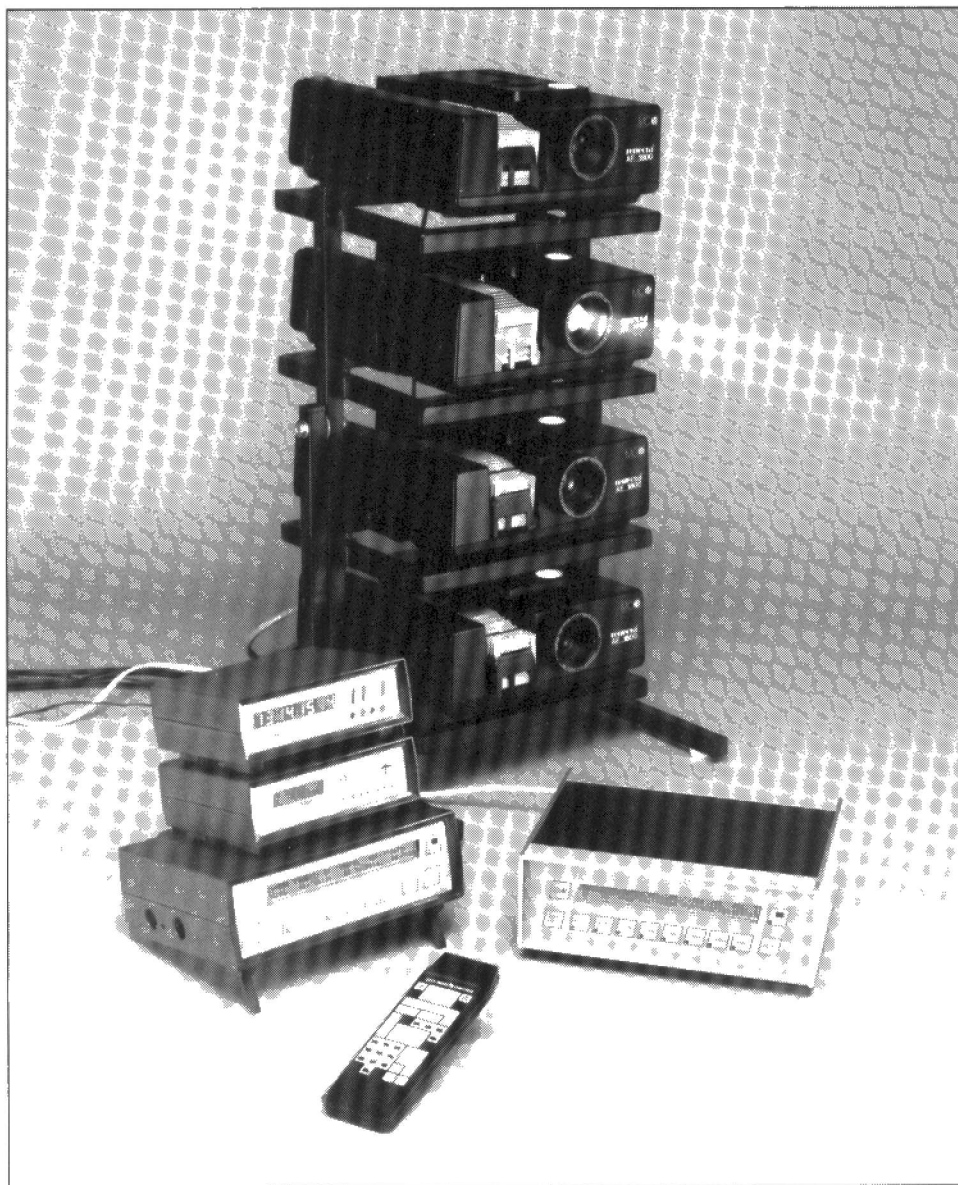
**CIS:** following reorganization, the state TV service 'Ostankino 1' is broadcast via the former CT-1 network. Identification is easy — a logo consisting of a large enclosed figure '1' is displayed in the corner of the picture. The news programme is called 'HOBCTN' (Novosti). The 'RTV' network is shown over the former CT-2 channels. The news programme is called 'BECTN' (Vesti).

This month's service information was kindly supplied by HS Publications (Derby, U.K.), Gösta van der Linden (Rotterdam, Netherlands) and the Benelux DX Club. Please write to the authors at the address below with DX-TV reception reports and news about developments affecting local television services in your particular corner of the world. □

Keith Hamer  
7, Epping Close,  
Derby DE3 4HR  
ENGLAND

# DIGITAL AUDIO/VISUAL SYSTEM

## PART 4 (FINAL): SOFTWARE AND MAIN UNIT TESTING



**This month we close the article with a description of the control software developed for the DiAV system. Also, we help you to test the main unit, and show you how to make a professionally finished infra-red remote control transmitter.**

**Design by A. Rietjens**

The main unit can be tested only if it is linked to an input device, for which there are two options: a PC-XT keyboard and an infra-red (IR) remote control transmitter. If you have the PC keyboard, you can start testing straight away. Not so with the IR re-

mote control, which has to be modified before it can be used. The self-adhesive front panel shown in Fig. 34 fits on an IRC301 remote control from Policom. This foil is pre-punched to avoid having to cut out the small rectangular holes for the keytops. To en-

able the foil to be secured on the front panel, you first have to open the unit. Remove the printed circuit board, the rubber feet and the switches. Next, remove the original self-adhesive foil. Before fitting the DiAV foil, check that this fits properly in the clearance. If necessary, cut off small parts until it fits exactly. Carefully stick the new foil on to the unit, and re-arrange the keytops according to the new layout. Coloured keytops may be used to highlight certain functions (see the front cover photograph of Reference 1). The 'refurbishing' work is illustrated in the photograph in Fig. 35.

Before closing the remote control again, we have to change its transmit address. A suggested address is 63. This can be achieved by leaving all jumpers on the RC-5 receiver module open, disconnecting pin 3 of the IR transmitter IC, and connecting pin 6 to pin 9 (see the example in the article covering the RC-5 IR receiver, Reference 2). The advantage of using address 63 is that the operation of the DiAV can not be disturbed by other remote controls, such as those used for most audio/video equipment. Having re-assembled the remote control, you are ready to embark on testing the main unit.

### Main unit testing

The main unit can only be tested if the Z80 card is fitted with the 27512 system EPROM and the two GALs that are supplied through the Readers Services as order code 6181. If the main unit has been constructed using the components listed in last month's parts list, the test and further construction will not cause problems. We base our test on that of the multi-purpose Z80 card. The differences are listed below — the points correspond to the test procedure given in the article on the Z80 card.

1. No remarks.
2. IC8 and IC9 are now replaced by DiAV decoders 1 and 2. Since we are to install 64 KByte of RAM, jumpers JP1 to JP5 have to be fitted at the RAM side. Also, since a 27512 EPROM is used, the memory configuration must be set to 'type 3' (con0 and con1 both at '1').
3. IC1 is now the DiAV EPROM (Type 27512). Since the MAX690 is not yet

fitted at this stage, it may be necessary to manually reset the Z80 card (press S1).

4. Fit extra IC2 (43256), IC6 (Z80B-P10), and connect the mini-keyboard described in Reference 3. On starting the system, the display indicates a RAM size of 64 kByte. Two beeps will sound, and the 'halt' LED will remain off. Since the DiAV control program and the Z80 BIOS are both contained in the EPROM, the software will enter the main program rather than the test routines. However, we first wish to test the card's functions, and this can be achieved by pressing a key on one of the input devices just after the first beep. The system then enters the test routines described in the article on the Z80 card. You are now ready to check the operation of the XT keyboard, the infra-red remote control and the mini-keyboard (depending on what has been connected). If the mini-keyboard is not connected, random key codes may appear that upset the normal operation of the system.

5. No remarks.

6. Since the AD7569 is not used, this test is dropped.

7. Connector K9 is omitted because the main unit has no separate printer output. The dissolve unit may be connected straight to K9. The text 'Test Dissolve Unit Y[N]' appears instead of 'Test printer Y/N'. Selecting 'Y' (yes), causes all dissolve units to be driven one after another, while the display shows a certain pattern. First, the lamp intensity changes from off to fully on. Next, the system issues nine forward and nine backward slide carrier commands. This is indicated by the displays counting up from 1 to 10, and down again. This test does not take account of any projectors actually connected. If there are, they are best switched off. If the IR remote control is used, check that the cursor keys can be used to toggle the default option: the indication 'Y/[N]' then changes into '[Y]/N'. Next, if any key is pressed, the test will be executed. Pressing 'ESC' or 'N' ends the test routines, whereupon the main program is started.

8. IC6 is already fitted, and reads the mini keyboard. The EXT1 and EXT2 connector may be used to hook up the timecode interface (or two of these using both connectors), as described in the previous instalment. This link is tested automatically by the DiAV software. In manual mode, 'm' is used to switch to monitor mode, and 'c' to set the speed as well as the inputs and outputs used (see the software description).

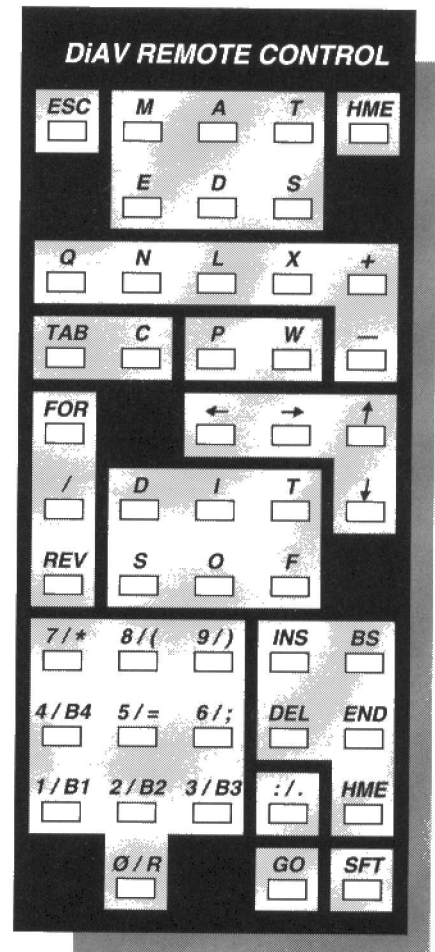
Having tested the basic functions of the main card as described above, we can concentrate on the DiAV control software proper.

## Main unit control software

After switching on, or after running the built-in system tests, a copyright message appears on the screen, and you are prompted to press a key. Next, you are taken into the main menu as shown in Fig. 37. The indicated functions may be selected either by pressing the cursor keys, followed by a 'return' ('GO'), or by typing the first letter of the option (this menu structure is, incidentally, supported by the Z80-BIOS, which may be of interest to those of you who use the Z80 card for applications other than the DiAV system). Below are brief outlines of the functions in the different modes of operation. A complete discussion of all functions and features may be found in the DiAV user manual, which may be printed from the disk supplied with the software package.

The remote control key legend shown in Fig. 36 provides a rough indication of the available functions. The keys are arranged in functional groups wherever that was possible — the emphasis is on the most frequently used functions.

For instance, a separate key field has been reserved for the selection of effects, carrier movement and speed. Another field has been reserved for the main menu. Options of the main menu and submenus that are not indicated may be selected with the aid of the



920022 - F2

Fig. 34. This front panel foil (available through the Readers Services; see page 70) replaces the one originally fitted on the Policom IRC301 infra-red remote control transmitter. The holes in the new front panel foil are pre-punched for your convenience.

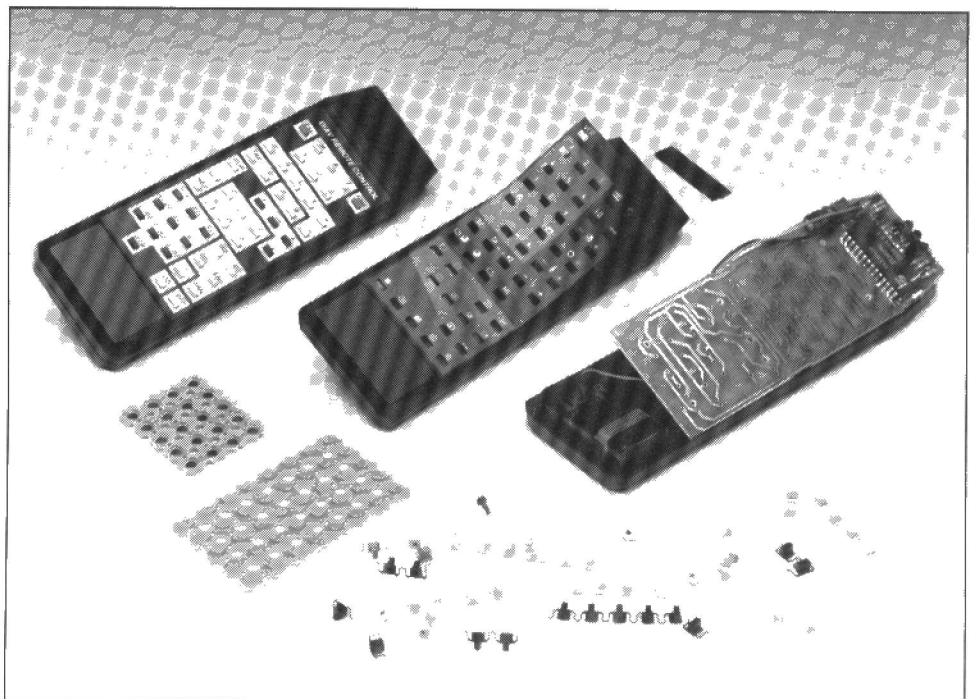


Fig. 35. After re-arranging the keys as required for the new front panel foil, you have a dedicated infra-red remote control unit that provides all the functions necessary to control the DiAV system.



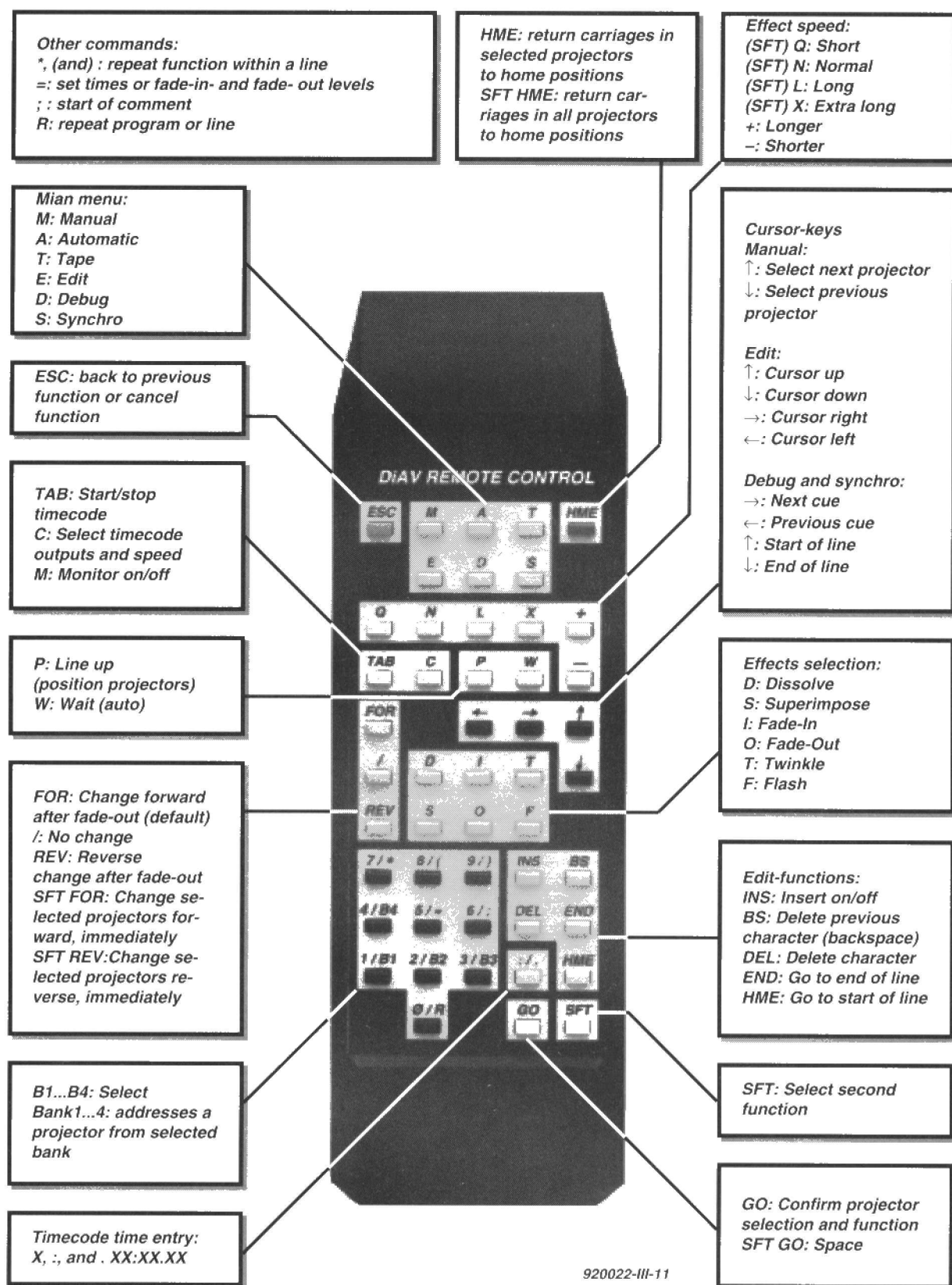


Fig. 36. This overview should help you find your way on the remote control transmitter key panel.

cursor keys.

Below are short descriptions of a number of functions offered by the system. The idea is to give you an impression of how the DIAV is operated, rather than to render a complete func-

tional description.

#### Manual

The system status menu appears after selecting the 'manual' option. This menu may be used at any time to see

what is happening. An example state is shown in Fig. 38. An indication is provided about the current slide in the projector, and whether or not this slide is projected. In the top right-hand corner you can read the time sent to the

timecode interface, and, next to it, the setting of this interface. The effect selected is 'superimpose' at a duration of 2,500 ms (adjustable in steps of 100 ms using the '+' and '-' keys).

Evidently, one of the most important functions in manual mode is being able to control a number of projectors in the simplest possible manner, in combination with the infra-red remote control. The key sequence 'I', 'D', 'N' and 'GO' ('enter' or 'space') on the PC-XT keyboard, for instance, causes projector 1 to do a 'dissolve', while all other projectors that were switched on do a fade, followed by a forward carrier change. For the next dissolve action, all you have to do is press the 'GO' key, whereupon projector 1 is dimmed and changes, and the selected project lights.

Since it is not easy to keep track of the projector selection, the following function has been added to the manual mode. After the system start, no projectors are selected. After each projector selection follows a comparison with the highest and lowest projector number entered so far. In case the new number (projector selection) is higher or lower than the one stored, the new value is stored, i.e., it overrides the previous one. In this way, the main unit 'remembers' the highest and lowest projector numbers. The last selection is stored, too. This data is used when the cursor-up and cursor-down keys are pressed. On pressing the 'I', '4' and 'D' keys, for instance, the main unit stores the value '4' as the highest (and last) projector number, and the value '1' as the lowest number. The effect chosen in this way is 'dissolve'. If 'cursor-up' is pressed next, the next projector, '1', is selected to do the dissolve. If you press 'cursor-down', the previous projector, '4', will do a reverse slide change, after which a fade-over is done. Slide changing will only be done if this is possible, so that the carrier is not pushed out of the projector! In this way, you can easily do fade-overs with several projectors, without being concerned all the time with knowing the next projector number.

If the timecode interface is connected, and the C (code) command is used to select output B, all selected functions will be recorded on to tape in the order as entered. This allows a slide series to be programmed in real time. A better and more comfortable way of doing this, however, is to enter a series via the editor function, and have it played back in automatic mode.

#### Automatic mode

An automatic series (of which an example is shown in Fig. 39) consists of the same commands as those used in

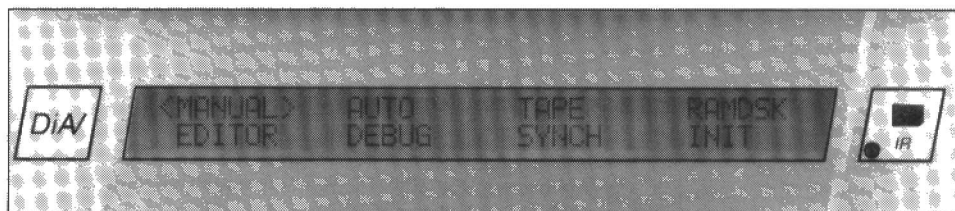


Fig. 37. LCD showing the main menu with the most frequently used functions.

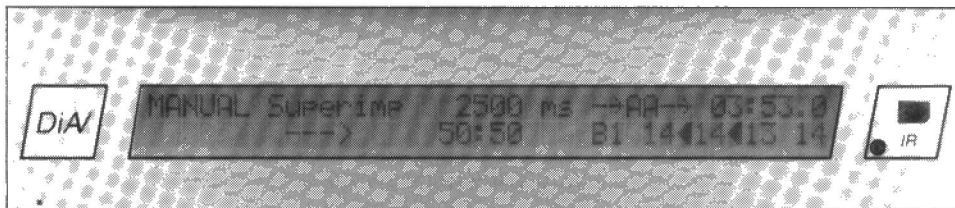
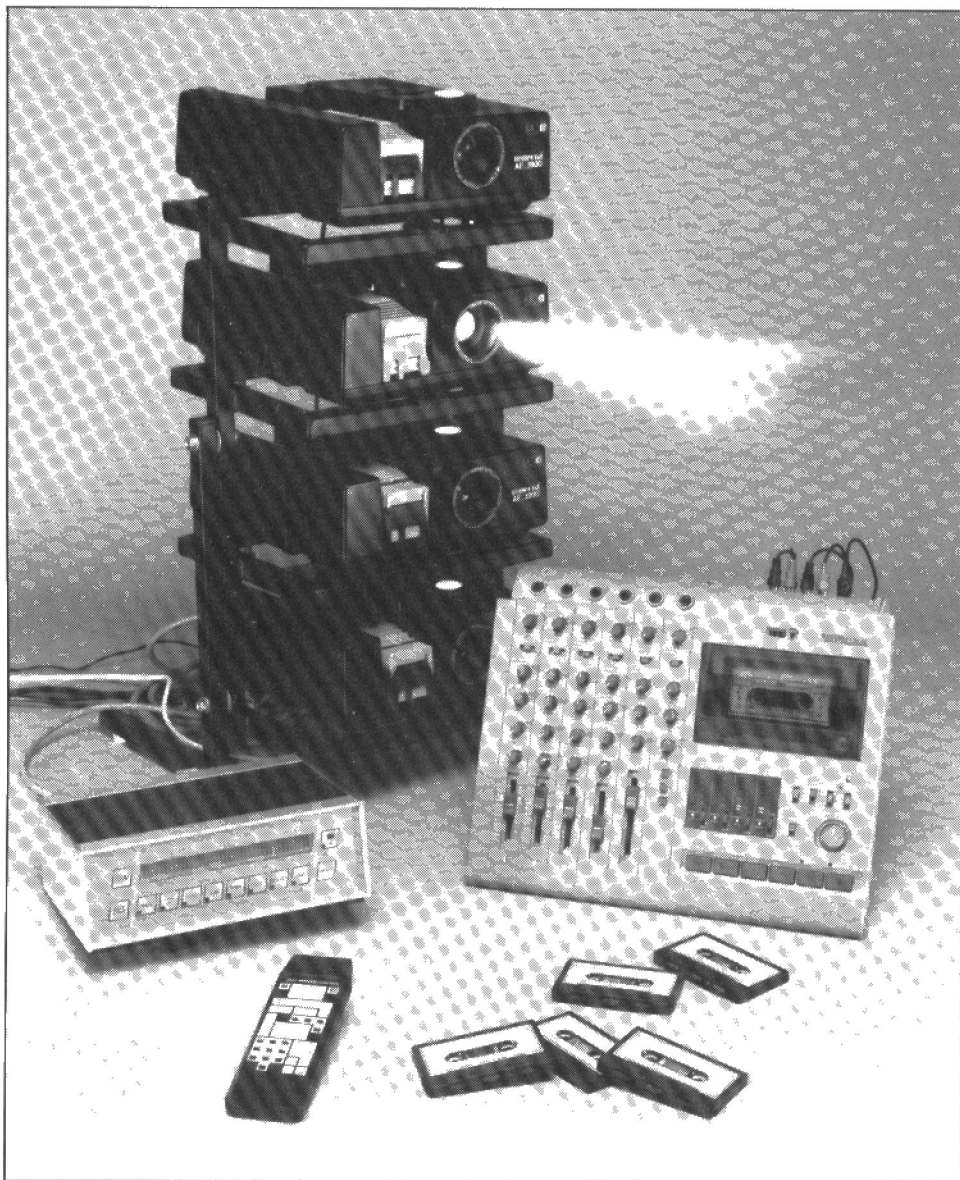


Fig. 38. Example of display indications in manual control mode.

manual mode. Such a series can be entered into the system via a PC, via the editor function, or via the serial interface. Cues (effects) are separated by a space, or the 'end of line' command, which equals 'GO' in manual mode. The maximum number of characters per line is 80. To be able to keep the command lines apart, it is best to enter a short description of its func-

tion at the end. Everything typed after a semicolon (;) is treated as comment. It is up to you to decide whether only one cue is used, or more cues. By contrast, most professional systems allow only one cue to be programmed per line. The advantage of being able to put two cues in a program line is that a slide series can be entered very rapidly.



```

(1) (d=2000 1 W1000 2 W1000 3 W1000 4 W1000 ) *5 ;show 20 slides
(2) (d=2000 s=70:70 1 W1000 2 W1000 3 W1000 4 W1000 ) *5 ;show 20 slides
(3) W (d=2000 s=70:70 1 W1000 2 W1000 3 W1000 4 W1000 ) *5 ;start on pulse
    synchronization
(4) (W d=2000 s=70:70 1 W1000 2 W1000 3 W1000 4 ) *5 ;pulse synchronization
    for each cycle
(5) W d=2500 s=80:80 1 W1500 2 W1200 3 W1400 4 ;
    W d=2000 s=60:60 1 W900 2 W1050 3 W1400 4 ;
    W d=1000 1 W100 2 W100 3 W100 4 ;fast
    W d=1750 s=50:50 1 W1300 2 W1780 3 W1200 4 ;
    W d=3500 s=90:90 1 W1000 2 W1000 3 W1000 4 ;
    W d=7000 o/4 ;slow fade out without change on last projector
(6) XX:XX.XX (d=2000 s=70:70 1 W1000 2 W1000 3 W1000 4 W1000 ) *5 ;auto-
    matic timecode insertion
(7) 01:00.00 (d=2000 s=70:70 1 W1000 2 W1000 3 W1000 4 W1000 ) *5 ;20 slides
    started with timecode
(8) 01:00.00 d=2000 s=70:70 1 01:03.23 2 01:06.56 3 01:09.45 4 ;4 slides exactly
    timed using timecodes
(9) 05:23.54 ix3 (w1000 fQ4 ) *4 (w500 fQ4 ) *6 (w300 FQ4 ) *7 ;fade in 3
    IL1 OL3/ (fQ4 w300 ) *12 fQ4 w200 >3 ;dissolve 3>1
    OX1 (FQ4 w300 ) *4 (fQ4 w500 ) *6 (fQ4 w1000 ) *4 >4 ;fade out 1

```

Fig. 39. Examples to illustrate how a slide show can be programmed with the aid of DiAV system commands.

The first programming example listed in Fig. 39 handles 20 slides (5 each on projectors 1, 2, 3 and 4) with a fade-over time of 2 seconds ( $d=2000$ ) and a projection time of 1 second ( $w=1000$ ). Such a setting can be used to build a complete slide show. If, for instance, slides have been arranged in pairs, and interesting additional effects appear to be possible, the system can be programmed such that a superimpose is used as a fade-over effect. Normally, the superimpose function has a 50:50 ratio, which means that the lamp intensity of the two projectors involved is controlled 50% of the total time reserved for the function. This results in a light intensity of 200% exactly half way the fade-over. If this gives a too strong image, it can be corrected very accurately by choosing a different superimpose ratio (e.g., 2). Note, however, that this does not change the total time defined for the function.

If you are satisfied with the slides, the combinations, the visual effects and the order in which the slides are shown, start thinking about your selection of music or comment (voice-over) to enliven the presentation. If pulse synchronization is used (via the pulse input) an endless loop (W) is put in those locations where we want to synchronize with the sound track. In

example (3), such a loop is only used to define the start point of the series. The complete series is started on detection of a pulse from the recorder. The waiting takes place in the loop. If we want to synchronize more accurately, for instance, once every four slides, the wait period is put inside the brackets, so that every cycle can be synchronized individually (in example (4), the last 'W1000' is, of course, omitted). The series can be perfected further by replacing all 'W1000' commands by 'W' commands. However, in practice it then becomes difficult to get all pulses in the right places, while erasing one of them is not all that easy either. In such a case, it is more convenient to write out the above example in the form of five separate lines, where synchronization takes place at one point in every line, and the absolute wait times are adapted for every individual slide. In example (5) we have added a command that 'closes down' the last projector, so as to create a good 'end' to the show.

Defining exact start points is much easier if the timecode interface is used. First, the timecode signal is recorded on a non-used track. During automatic mode, the time read back from the tape is taken as the system time. In the program, we enter 'XX:XX.XX' instead of the 'W' command (example

6). This enables the desired time to be filled in automatically on pressing a random key (7). In this way, the start point can be fixed by the timecode synchronization.

The timecode interface gives you a very accurate control over the whole timing of the slide presentation. Fine tuning is also much simpler than with pulse synchronization: after setting the times intuitively, you may correct them manually in very small steps (10 ms), as illustrated by example (8).

So far, the examples have been relatively simple. We do, however, want to give a more extensive example that illustrates the use of only three slides (loaded on projectors 1, 3 and 4). Example (9) starts from a quenched projector, and fades in (i) a slide (3) slowly (x), after which a fade-over is done (IL1 OL3/) into a second slide (1), whereupon a fade-out (O) is done. At the same time, a third slide (4) flashes (f) at a changing rate (w300, w500 and w1000). The images used for the fade-over could be those of a pop group, while the flashing slide provides the light effects. The user manual contained on the diskette supplied with the DiAV software package gives short examples to illustrate the effect of each of the user options.

### Debug and synchro

Programming a slide presentation is, of course, never as simple as described above. In nearly all cases, errors will be made which require simple and effective debugging tools. For these, the DiAV control software offers you the 'debug' and 'synchro' functions. In debug mode, you can execute either each individual line or each individual cue, in both directions! The projectors simply 'follow' the cursor, which enables you to spot the faulty command very quickly, and correct it using the editor mode. If you want to look for a specific position without seeing all cues along the program faithfully executed, use the 'synchro' function rather than 'debug'. Synchro allows you to step through the program without projector action. Once you have arrived at the desired position (and, if necessary, found the corresponding tape position), you can change to 'debug' or automatic mode to run or correct the series from there on. For this it is necessary that the projector carriers are automatically moved to the desired positions, and the relevant lamp intensities are set up. This allows the series to be continued from that point onward.

### SDL (Special Data Language) and tape mode

After a slide show has been put together with the aid of timecode syn-

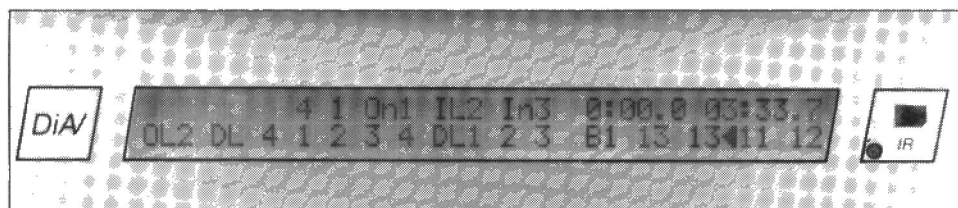


Fig. 40. In tape mode, all commands read from the tape recorder are displayed on the LCD.



chronization, it is desirable to link the control program to the sound tape. Apart from the series itself, the current projector parameters (lamp intensity, carrier position) have to be recorded also. Being able to read this information from tape at any tape position allows us to adapt the projector states as required. This is achieved by the SDL code, which, apart from the commands that make up the series, also contains the current projector parameters such as the effect chosen, fade-over time and carrier position. Writing to tape is effected in parallel with the music, so that the series is securely linked to the location where 'it is to happen'. If the music tape is started somewhere in the middle of a series, the DiAV main unit is still capable of moving the projector carriers to the desired slide position, and start again from there. In practice, this will not be done too often, but such a test clearly demonstrates the error correcting capabilities of the SDL code. If, during the show, errors occur owing to tape drop outs, you can be sure that the system is capable of correcting these, and making the show continue practically without a hitch.

Furthermore, the SDL code itself is protected against read errors. All codes receive an error correction block before they are sent to the tape. This is achieved by 'Hamming' encoding, a technique widely used in telecommunications. This encoding system affixes

**Table 5. Timecode interface settings**

<b>General:</b>	'A' input used for reading from timecode interface; 'A' output for writing to timecode interface. 'B' input used for reading SDL code; 'B' output for writing SDL code.
<b>Manual:</b>	according to 'C' command option.
<b>Auto:</b>	Read timecode via input 'A'. Write SDL code via output 'B'.
<b>Tape:</b>	Read SDL code via input 'B'.
<b>Debug:</b>	Read timecode via input 'A'.
<b>Syncho:</b>	Read timecode via input 'A'.

a number of extra bits to each byte to be transmitted: three for each nibble. That is why an SDL byte is actually transmitted as two bytes. The structure of the Hamming codes enables a byte of which one bit goes wrong to be reconstructed on the basis of the remaining information. In short, this results in an extremely reliable decoding process.

The SDL code is sent to tape via the 'B' output on the timecode interface, in manual or automatic mode. During projection in automatic mode, the timecode interface is automatically given the proper settings, and the SDL code is always transmitted. In manual mode, the SDL codes are only transmitted if output 'B' has been selected on the timecode interface, with the aid of the C (code) command.

Reading and recording SDL codes takes place in 'tape' mode. Commands read from tape are sent to the main unit display in chronological order (see Fig. 40).

#### Remaining functions and features

The functions described above form the core of the software. In addition to these, there are functions to control the RAM disk (read, write, erase and directory), and to change a miscellany of basic settings (with battery backup), including the 'one-button/two-button' projector type selection. A full description of these features may be found in the user manual contained on the system diskette.

#### DiAV software for IBM PCs and compatibles

Since it is often more convenient to type in a lengthy program on a larger screen, the DiAV system has been endowed with a program download feature that works in conjunction with IBM PCs and compatibles. The download utility allows you to control the main unit (via the PC's COM1: or COM2: serial port) as if this had its own, local, keyboard. In addition to this function, the download utility also allows programs to be sent to, and read back from, the main unit.

Additionally, the software offers the possibility to make a back-up copy of the entire RAM-disk. This may be done to save complete programs on to hard disk or floppy disk, from which they can be retrieved and downloaded to the DiAV system at any time. Making back-up copies of programs on disk is good practice because the memory back-up battery in the main unit will not last forever! It should be noted that the DiAV system disk does not contain software to drive the dissolve unit or the timecode interface from the PC.

In contrast with the main unit local control software, the PC DiAV downloader does not contain a text editor. However, any word processor capable of saving and loading straight ASCII files may be used for this purpose, even the most rudimentary of these, EDLIN (found in your DOS directory). To make sure that the DiAV programs are easily found back, they are best stored in a separate subdirectory.

#### Conclusion

This last article instalment has aimed at giving you a first impression of the many features of the DiAV system, without attempting to be complete in any way. As already mentioned, all system functions are described and illustrated at length in the 40-odd page user manual which you can print from the system diskette.

After the first faltering steps in operating and programming the DiAV system, you will soon get the hang of it, and agree with us that things look a lot less complex than initially feared. Every module, however, takes some getting used to. For example, the comforts of using the timecode interface will not be appreciated until you have grown accustomed to using this unit. ■

#### References:

1. *Elektor Electronics* November 1992.
2. *Elektor Electronics* January 1992.
3. *Elektor Electronics* December 1992.

### DiAV PROJECT SOFTWARE

The software for the DiAV system consists of EPROMs, GALs and an IBM PC diskette. This is the 'basic version' of the software for up to four slide projectors.

For the **dissolve unit** you need EPROM 6171 (a 2764). This may be obtained separately, but it is also supplied with the dissolve unit PCB, order code 920022.

For the **Z80 card** you need IC set 6181, which consists of one EPROM (27512), two GALs (20V8) and one 3½-inch floppy disk (IBM PC format).

Prices and ordering information regarding these items may be found on the Readers Services page.

**Extended system software** for 8, 12 or 16 projectors is available from DiAV Digital AV, P.O. Box 2797, 6030 AB, Nederweert, Holland. Also contact DiAV Digital AV for information on updating from the basic 4-projector version to a larger version.

# READERS' CORNER

## LETTERS

### SECAM-TO-PAL TRANSCODER

Dear Editor—In view of your readers' request for a SECAM-TO-PAL transcoder, the following extract of my magazine may be of interest.

Having watched the transmissions from Telecom IC for about 6 months, I figured it was about time I acquired a SECAM-TO-PAL transcoder. This is a simple device that converts the SECAM to the PAL transmission standard. Leafing through the adverts though, I found most cost about £125, which is a ridiculous price. The only option was to build one, but amazingly I found none of the electronics magazines had ever published such a circuit, or had any intention to.

There are ICs available for this purpose, such as the Philips TDA3592A. The application circuit can easily be assembled on Veroboard (but you should remember to leave room in the layout for the two delay line). The biggest problem I had was locating a circuit for supplying the sandcastle pulse which the chip needs, but eventually I found one in the October 1990 issue of *Elektronika* ('S-VHS/CVBS-to-RGB Converter').

The TDA3592A has separate luminance/chrominance inputs, intended for feeding into a PAL decoder chip within a TV and not for producing a summed composite video output. The signals cannot be summed directly, as this creates a chrominance beat effect. So

the luminance output (pin 15) has to be devoid of any chrominance signal. I found that two trap filters were required on the output before mixing the signals together. Of course, this will remove the chrominance from PAL signals, unfortunately leaving them black and white. The signals are then mixed via two level presets that feed into an emitter follower, followed by a standard two-transistor (PNP/NPN) video amplifier output stage.

The sandcastle pulse should be fed into both pins 4 and 19 of the IC, which gives line and frame identification. Inductors  $L_1$ – $L_4$  are Toko Type MKANK4174HM (available from Cirkuit) with 360 pF in parallel. Alignment really requires a SECAM test card source and, although not essential, an oscilloscope will prove useful.  $L_1$  is adjusted for minimum colour on black: either side of the correct setting will give excessive red or blue. The 1 k $\Omega$  preset across  $L_1$  is a  $Q$  control; adjust this for correct colour saturation.

A big problem with the TDA3592A is that there is no Bruch blanking, which means the colour bursts continue into the vertical blanking interval. This not only stops Teletext being decoded properly, but also creates a vertical jitter in the picture, the degree of which will depend on your TV. My Sony receiver was not too bad, but when I tried to record the signal on my VCR, the jitter was terrible. A Bruch blanking circuit could be made by using the vertical sync. pulse to gate out the

chrominance signal (pin 14). A few transistors can detect the pulse and trigger a monostable, the output of which can be fed to a switching transistor. I never bothered with this, since I found a bodge cure that proved satisfactory for my purposes (although the Teletext still doesn't work). This simply entails putting a low level of capacitance across the chrominance output! I can only assume this works by the phase shift it creates; the same effect cannot be achieved by attenuation of the chrominance signal. Of course, this affects the orthochromaticism of the picture but, unless you spend all your time watching testcards, it isn't that noticeable. The overall cost of the circuit should not be more than £20, a considerable saving over commercial units.

The TDA3592A development data (which includes the application circuit referred to) may be obtained by sending an A4 s.a.c. to **Philips Components Ltd, Mullard House, Torrington Place, London WC1E 7HD.**

The Philips 470 ns and 64  $\mu$ s delay lines were obtained from **Sendz Components, 63 Bishopsteignton, Shoburyness SS3 8AF.**

G. Franklin, Canvey Island.

### HAPPY WITH 8751 EMULATOR

Dear Editor—Thank you for your fine magazine and products. I would like to say how happy I am with the 8751 Emulator that I

## EVENTS

### IEE AND IEEIE PROGRAMME

- 1 Feb—Microstrip patch antennas.
- 2 Feb—The future for research in transmission and distribution in the UK.
- 2 Feb—Accreditation of RF measurements.
- 3 Feb—Multimedia and professional applications.
- 4 Feb—Does electromagnetic modelling have a place in EMC design?
- 5 Feb—Masterclass in systems engineering.
- 8 Feb—Implications of modern metering.
- 9 Feb—Initial verification of electrical installations.
- 10 Feb—Silicon-based optical electronics.
- 10 Feb—Cellular manufacturing.
- 10 Feb—Design calculations for small electrical installations.
- 11 Feb—Electromagnetic aspects of semiconductor devices.
- 11 Feb—10th COMPUTING AND CONTROL LECTURE: Policy choice for IT in the EC.
- 15 Feb—Field programmable gate arrays.
- 16 Feb—New directions in adaptive signal processing.
- 16 Feb—The intelligent network – fact or fantasy?
- 16 Feb—Electricity at work regulations.
- 17 Feb—Portable appliance testing.
- 17 Feb—Terrestrial DAB (digital audio broadcasting) – where is it going?

- 17 Feb—So what is power electronics anyway?
- 17 Feb—Pulsed power '93.
- 18 Feb—In-vehicle systems and the driver interface.
- 18 Feb—Overhead transmission lines – refurbishment and development.
- 18 Feb—Circuits and systems.
- 18 Feb—Periodic inspection and testing of electrical installations.
- 18 Feb—Electromagnetic compatibility for project engineers.
- 22 Feb—Robert Watson Watt – the father of radar.
- 22–25 Feb—Design automation (European conference in Paris. Details from CEP Consultants, 26–28 Albany Street, Edinburgh EH1 3QH; phone 031 557 2478.
- 23 Feb—Significance of calibration.
- 23 Feb—NCVQ (National Council for Vocational Qualifications) – its influence in higher education.
- 24 Feb—Computer modelling and simulation of radar systems.
- 26 Feb—Microwave tagging.

Further information on these, and many other, events may be obtained from the IEE, Savoy Place, London WC2R 0BL; Telephone 071 240 1871, or from the IEEIE, Savoy Hill House, Savoy Hill, London WC2R 0BS; Telephone 071 836 3357.

### EMC93 – COMPATIBILITY FOR LIFE

ERA Technology's 8th annual conference and exhibition on electromagnetic compatibility will focus on the problems of designing and manufacturing products that will maintain their compatibility throughout their service life.

EMC93 'Achieving whole-life EMC: management, design and compliance' will be held on 18 February at the Heathrow Penta Hotel.

Further information from Laura Christie, Principal Conference Organizer, ERA Technology, Cleeve Road, Leatherhead KT22 7SA; Telephone (0372) 374 151, Ext. 2290.

### NEPCON WEST '93 TO BE EARLIER

Nepcon West '93, the National Electronic Packaging and Production Conference, returns to Anaheim, California, two weeks earlier than usual: 9–11 February. The conference sessions begin on Sunday, 7 February.

One of the five shows this largest manufacturing electronics exhibition in the U.S. consists of is Surface Mount Technology, the largest SMT event in the United States.

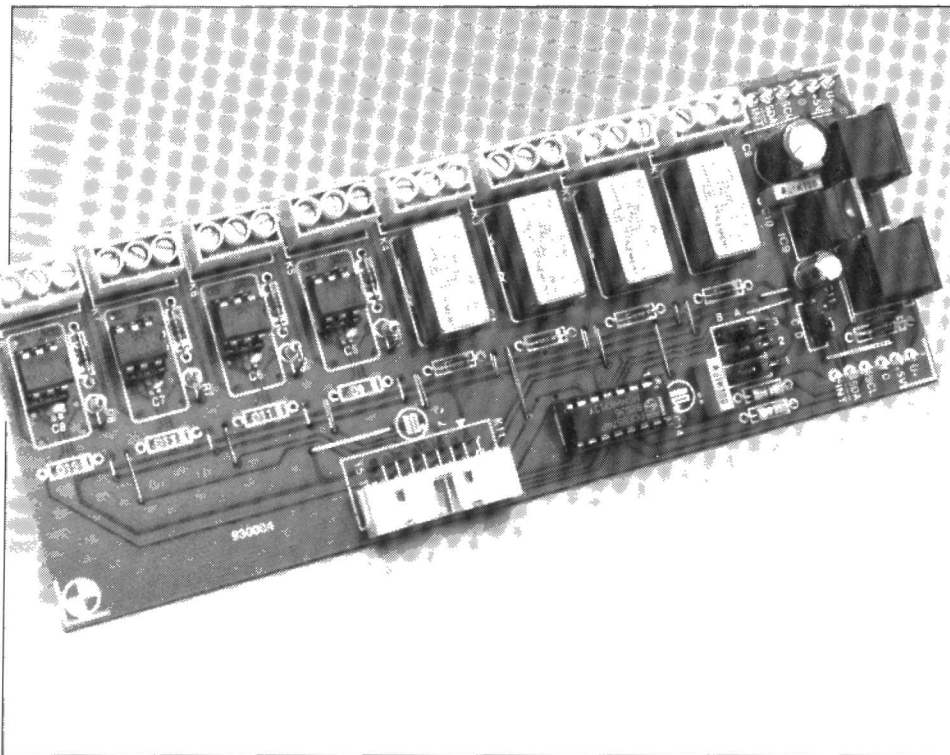
For information on the exhibition, contact Janet Schafer, Director of Nepcon, Reed Exhibition Companies, Inc., 1350 E. Touhy Ave., Des Plaines, IL 60017-5060. For conference information, contact Michael Critser at the same address.





# I<sup>2</sup>C OPTO/RELAY CARD

## PLUS A NEW I<sup>2</sup>C DEVICE DRIVER (V 1.1)



The popularity of our series on I<sup>2</sup>C devices is still growing, and that is why we venture to propose a real-world interface for the I<sup>2</sup>C bus. The eight channels on the interface described here are electrically isolated by optocouplers or relays, and operate under the control of I<sup>2</sup>C bus commands. If you need more than eight channels, it is possible to put up to seven more cards on to the bus.

Design by J. Rutgers

SINCE its introduction, the software we proposed to control I<sup>2</sup>C devices via a PC has been improved in a number of ways. Before discussing the relay/opto card, we will have a look at the improvements.

A time-out check has been added to the Wait Byte routine contained in the device driver I2CDRIV2.SYS (I2CDRIV2.ASM). This addition produces an error code if the specified wait time (default: 1 s) is exceeded when waiting for a byte to arrive via the I<sup>2</sup>C bus. This effectively prevents the PC being lost in an endless wait loop when there are errors in an I<sup>2</sup>C communication.

Furthermore, one bug has been fixed, and the communication between the PC and the PCD8584 (I<sup>2</sup>C bus controller) has been improved. The latter modification was made when we found that the CS pin has to be inactive suf-

ficiently long in between two cycles. The datasheet mentions the following in this respect: "If the I<sup>2</sup>C controller runs at a clock speed of 8 MHz or 12 MHz, the minimum number of clock cycles between any two actions on the data bus is six. At lower clock speeds, this may be reduced to three cycles". Mind you, the datasheet mentions the controller's clock speed, not that of the PC. In practice, the modern generation of PCs, for example 486-core 33-MHz machines, are far too fast for the I<sup>2</sup>C controller. To solve the problem, a subroutine doing a number of NOPs (no operation) is called after each input or output instruction. The number of NOPs required depends on the clock speed of your PC, and may be defined by trial and error (as indicated by the datasheet, there is a certain spread). The number of NOPs inserted by the driver is conveniently defined

via the CONFIG.SYS file, which may look like this:

```
DEVICE = I2CDRIV2.SYS B:300 C:0
D:00FF
```

where the 'D' parameter indicates the number of NOPs. The default value is 00FF<sub>H</sub>, which works fine on a 33-MHz 486 PC. The optimum value (i.e., the smallest possible value) may be established by experiment only. The smallest delay you can enter is 0001. Finally, the driver now includes routines that read the 'D' parameter, and puts it on the screen. These routines go by the name read\_nop\_num and print\_nop\_num.

The PASCAL unit for the I<sup>2</sup>C interface has also been modified slightly. The new unit, I2C2.PAS, enables error reports to be handled from within the main program. The new routine is contained in the G\_IO subdirectory on the floppy disk, together with G\_IO.PAS, a demo for the opto/relay card.

The new software may be obtained as order code 1821, and replaces the old version, 1671. For price and ordering information, you are referred to the Readers Services on page 70. Please note that the older version can not be exchanged for the new one.

### The opto/relay card

The circuit diagram of the opto/relay card is drawn in Fig. 1. The heart of the circuit is formed by IC10, a PCF8574. This IC may be familiar from the A-D/D-A card in the I<sup>2</sup>C module series (Ref. 1). The PCF8574 is an 8-bit parallel I/O port located at base address 4xH on the I<sup>2</sup>C bus. The value of 'x' is determined by jumpers JP1, JP2 and JP3 which are connected to address lines A0, A1 and A2. The least significant bit of the address byte is used to indicate write or read actions to or from the IC. In binary form the address looks like this:

```
0 1 0 0 A2 A1 A0 R/W\
```

where W\ stands for the inverted write signal. The jumpers thus allow you to select between eight addresses, which is also the maximum number of opto/relay cards that can be put on to the I<sup>2</sup>C bus. However, any other cards that have a PCF8574, such as the A-D/D-A, are to be included when totalling up!

Although the circuit diagram would appear to show that the databits are connected to a relay and an optocoupler, they are, in fact, connected to a relay **or** an optocoupler. The selection between optocoupler and relay is made by a jumper on the printed circuit board. The two can **not** be used at the



same time, which would be very strange anyway from a point of view of electronic design.

None the less, the opto/relay circuits are designed such that the same PCB layout is used to build either an optocoupler input or a relay output. It should be noted that the bits defined as an input must be initialized by writing logic 1s to them.

The relays used are polarized types. The cores of the relay coils contain small permanent magnets whose force is just too small to pull in the contacts. By virtue of the magnetic field built up by the permanent magnet, the coil has

to overcome only a small force to pull in the contacts and keep them closed. The advantage is clear: the coil current required to energize the relay is considerably reduced. However, this is only true if the coil is supplied with the correct polarity. If not, the purpose of the permanent magnet is defeated, since the coil and the core then operate against each other.

The power supply on the card contains a jumper (JP4) that enables the relays to be powered by a separate supply. This may be necessary in some cases to reduce the total load on the I<sup>2</sup>C bus 5-V supply line. If the jumper

## MAIN SPECIFICATIONS

Relay outputs:	2 A; 150 Vdc; max. 60 VA
Port outputs:	5 V; 25 mA sink; 400 $\mu$ A source.
Opto inputs:	5-15 V (4-14 mA) with polarity re- versal protection. Other ranges possi- ble by changing R1-R8.
Port inputs:	TTL level
Base address:	4x <sub>H</sub> (max. eight PCF8574 mod- ules on bus)

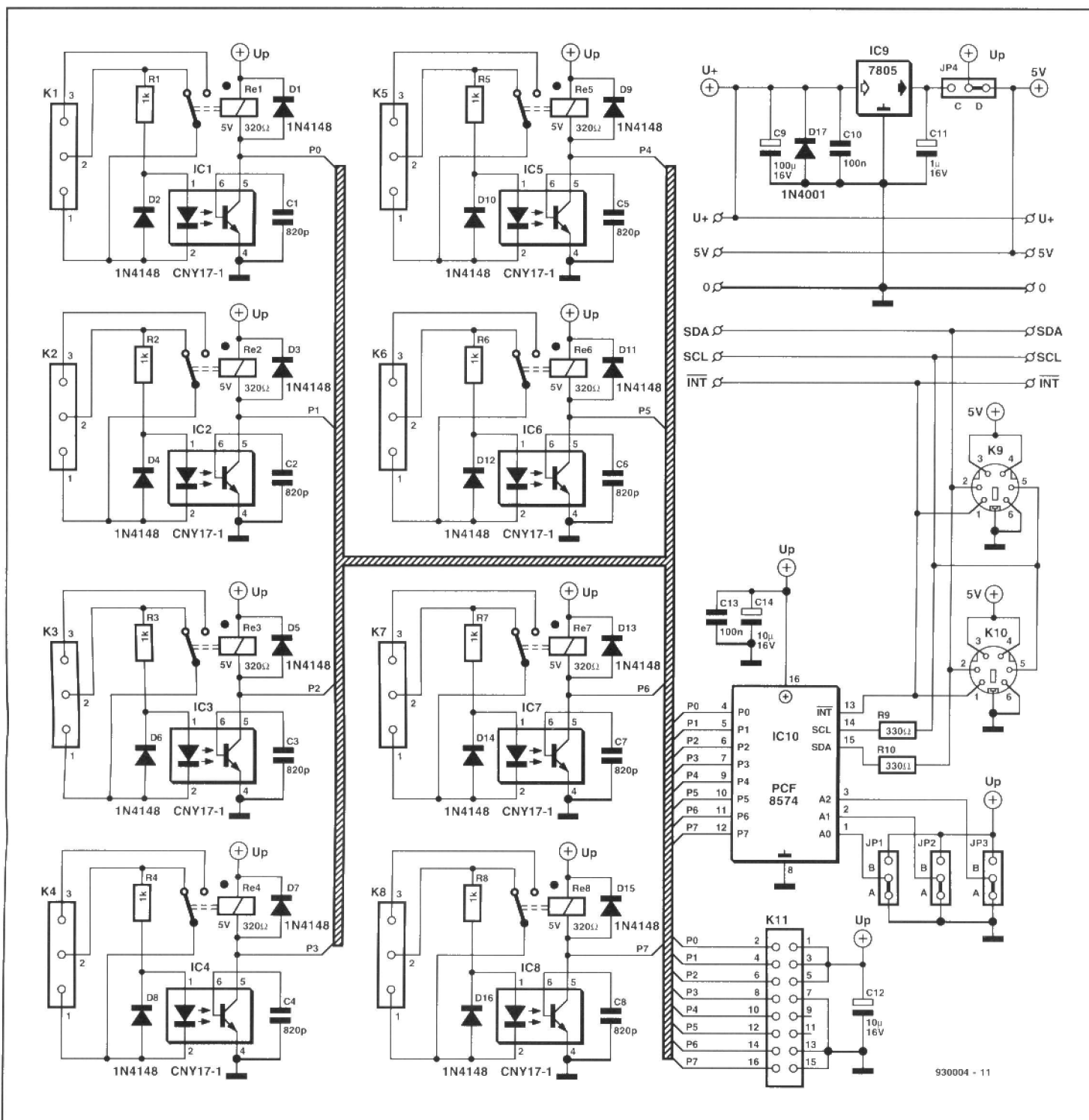


Fig. 1. The circuit diagram of the 8-way I<sup>2</sup>C input/output card is simplicity itself. Note that only one LSI IC is used.

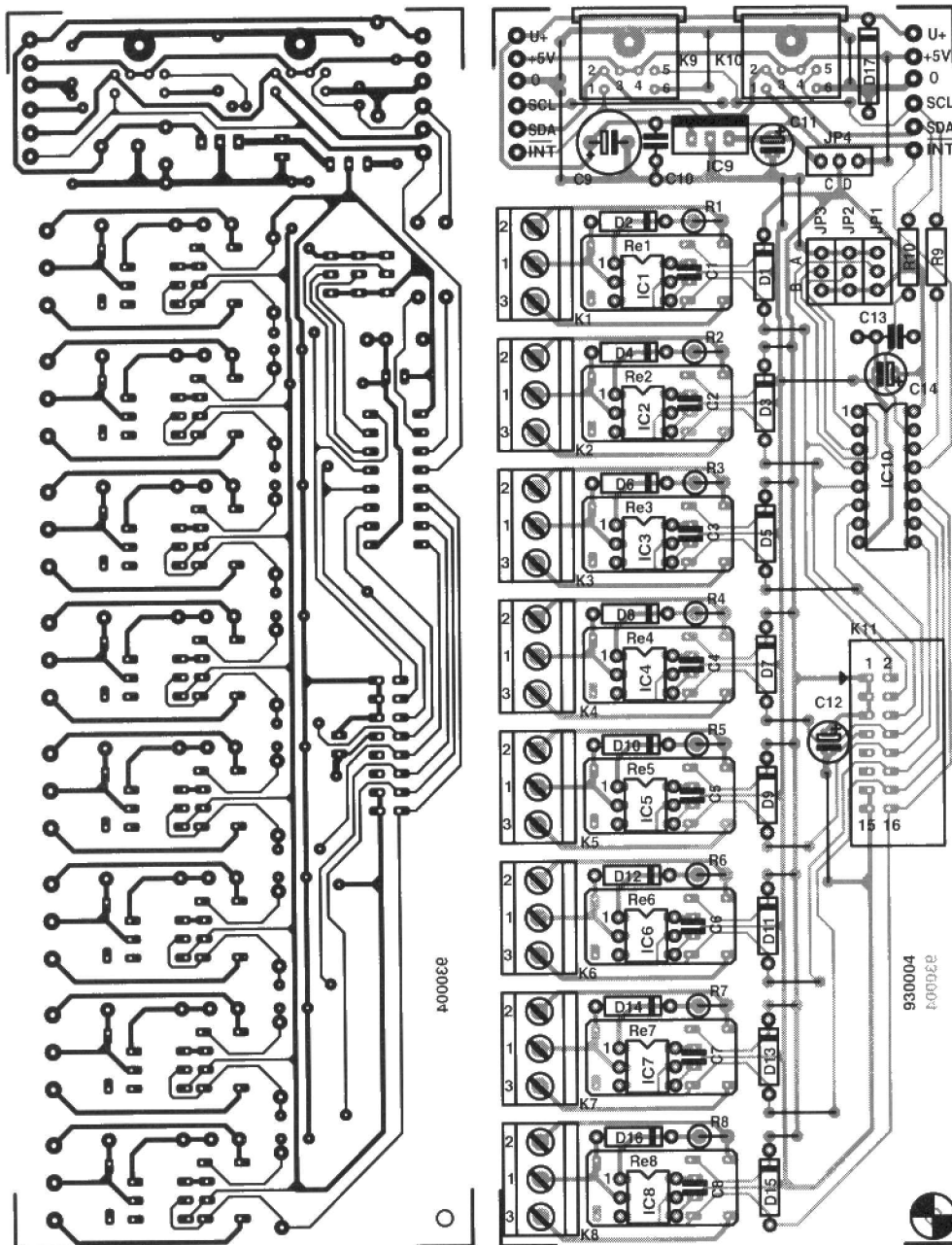


Fig. 2. The PCB design is such that the hardware of each I/O bit consists either of a relay (bit = output), or an optocoupler (bit = input).

is fitted in position 'C', the relay current is drawn from an external source (8-15 V) via the PCB terminal marked 'U+'. In most cases, this will only be necessary if two or more relay cards are used, since the 5-V supply in the PC can deal with pretty heavy loads. If you do not need to resort to an external supply, fit JP4 in position 'D'. You may then omit components IC9, C9, C11 and D17 (supply reversal protection).

## Construction

The construction of the present I<sup>2</sup>C extension card is entirely straightforward. The artwork of the single-sided printed circuit board for the I<sup>2</sup>C opto/relay card is given in Fig. 2. As you can see, it is impossible to connect an optocoupler **and** a relay to one and

the same bit.

The parts list indicates components required for an 'input' configuration (optocoupler) with one asterisk (\*), and components required for an 'output' configuration (relay) with two asterisks (\*\*).

The specification and the PCB layout make it quite clear that the circuit is **not suitable for connecting to the mains**.

## Testing 1, 2, 3...

The program G\_IO.PAS may be used to test the hardware, provided it is adapted to match the input/output configuration of the card. It is also eminent for the design of your own applications. Those of you who do not have a Pascal compiler may use the executable file G\_IO.EXE. Note, however,

## COMPONENTS LIST

\* = Components for input configuration (optocoupler).  
 \*\* = Components for output configuration (relay).

### Resistors:

8 1kΩ\* R1-R8  
 2 330Ω R9;R10

### Capacitors:

8 820pF\* C1-C8\*  
 1 100μF 16V radial C9  
 2 100nF C10;C13  
 1 1μF 16V radial C11  
 2 10μF 16V radial C12;C14

### Semiconductors:

8 1N4148\*\* D1;D3;D5;D7;  
 D9;D11;D13;  
 D15  
 8 1N4148\* D2;D4;D6;D8;  
 D10;D12;D14;  
 D16  
 1 1N4007 D17  
 8 CNY17-1\*+ IC1-IC8  
 1 7805 IC9  
 1 PCF8574 ++ IC10

### Miscellaneous:

8 3-way PCB terminal block; pin grid 5mm K1-K8  
 2 6-way PCB-mount mini-DIN socket K9;K10  
 1 16-way angled box header K11  
 8 V23040-A0001-B201 + relay (5V 320Ω) Re1-Re8  
 1 Printed circuit board; order code 930004 (see page 70)  
 1 Software on disk; order code 1821 (see page 70)

+ Siemens product. Suggested retailer: ElectroValue, 28 St Jude's Road, Englefield Green, Egham, Surrey TW20 0HB. Telephone: (0784) 433603. Fax: (0784) 435216.

++ Philips Semiconductors product. Suggested retailer: C-I Electronics, P.O. Box 22089, 6360 AB, Nuth, Holland. Fax: +31 45 241877.

that G\_IO.EXE assumes that there are relays in positions Re1-Re4, and optocouplers in positions IC5-IC8. This program runs a switching sequence on the relays, and subsequently puts the current input levels on the screen. G\_IO.EXE also assumes that the opto/relay card is located at address 40H (JP1-JP3 in position 'A'). ■

### Reference:

1. ADC/DAC and I/O for I<sup>2</sup>C bus. *Elektor Electronics* March 1992.

# 1.2 GHz MULTIFUNCTION FREQUENCY METER

## PART 3: THE PC LINK

Design by B.C. Zschocke

This month's instalment explains how the frequency meter can communicate with a PC via an RS232 serial link. Obviously, to be able to write and download user control programs to the instrument, you require full descriptions of the various functions available. These descriptions are given here, but before we start listing them it must be mentioned that PC control of the counter is optional, and offers no extra functions over and above manual control (described last month). So, do not worry if you do not have a PC — this instalment is simply not for you. The PC link is, however, a jewel for anyone involved in automated test, measurement and data logging systems, since it allows measurements to be set up and timed, and measurement data to be collected, in the absence of an operator.

The control of the instrument via the PC is basically the same as manual control. Last month we already mentioned that manual control (i.e., pressing the keys on the instrument) builds a string of commands that is stored internally and executed after the start command. Well, the PC link does the same: commands are entered into the instrument in the form of codes, which you may have spotted already in the large menu overview presented in part 2 of this article (hexadecimal codes in the upper left hand corners of most of the boxes). The PC link uses the same command storage locations in the instrument as manual control, while the same options and parameters are available. The measurement results stored in the instrument may be read by the PC for processing. In the following description, the storage locations addressed by the PC are called **registers**.

### Hardware

Two points should be noted in relation to the RS232 link between the counter and the PC. First, the PC should have an active RS232 port, because the RS232 line voltages are used to power the level converter in the counter. Second, bear in mind that the

counter's ground is connected to the RS232 interface ground, which means that it is also connected to the mains earth via the PC. Consequently, measurements carried out with the counter are **not** potential-free, which requires extra care in some cases. An electrically isolated RS232 interface that can be used on the counter is planned for a future issue of *Elektor Electronics*. Such an interface enables a potential-free measurement system to be set up.

### PC link basics

Start by connecting the counter's serial port to the RS232 port on the PC. Next, initialize the PC port so that it runs at **2,400 baud, 1 start bit, 8 data bits, no parity**. This may be done under DOS using the MODE command, or by a communication program. Make sure that the RTS line is properly initialized. Although this is done automatically by the DOS MODE command, it may have to be arranged otherwise on other computers.

The next phase is simple: switch the counter to its start (default) state. This is achieved by switching on the instrument, or pressing the BREAK key.

The communication between the PC and the instrument is based on the full ASCII code set. The characters 0<sub>H</sub> to 1F<sub>H</sub> are used for the commands, and the remainder of the set (20<sub>H</sub> and higher) to identify the functions (command parameters). ASCII values up to 1F<sub>H</sub> have three-letter codes which are remnants from the telegraphy age. These letter codes are used in the descriptions below, instead of the hexadecimal values. An overview of ASCII values and corresponding telegraph codes is given in Table 1.

So far, so good. Now, the PC waits for data. If it receives a DLE code (10<sub>H</sub>), this must be taken to mean that connection is not possible. In that case, the counter has to be switched off and on again, or force it to transmit a SYN (16<sub>H</sub>) code by pressing the BREAK key. Reception of a SYN code at the PC side means 'connection possible'. The ensuing wait state is marked as 'NC' (for

Table 1. ASCII command set

Decimal	Hexadecimal	Code
0	00	NUL
1	01	SOH
2	02	STX
3	03	ETX
4	04	EOT
5	05	ENQ
6	06	ACK
7	07	BEL
8	08	BS
9	09	HT
10	0A	LF
11	0B	VT
12	0C	FF
13	0D	CR
14	0E	SO
15	0F	SI
16	10	DLE
17	11	DC1
18	12	DC2
19	13	DC3
20	14	DC4
21	15	NAK
22	16	SYN
23	17	ETB
24	18	CAN
25	19	EM
26	1A	SUB
27	1B	ESC
28	1C	FS
29	1D	GS
30	1E	RS
31	1F	US

'not connected') in the following diagrams. Manual control of the counter is only possible in NC mode.

On reception of a SYN code, the PC can request the connection to be set up by issuing an ENQ code. In response, the counter establishes the link, and supplies an ACK (acknowledge) code. From then on, the counter is in connect mode (C), which puts the PC in control. In connect mode, a measurement can only be started. All setting-up has to be done beforehand. Thus, before a measurement can be started, the PC must send a series (string) of commands and parameters that selects, for example, the counter function, the input, the gate time, etc. This can only be done in command entry (CE) mode, which is selected by sending an STX code to the counter. In this mode, each received code is written into the counter's command memory, until the command is complete. An ETX code switches the counter back from CE mode to C mode. The command string built by the PC is fetched from the memory and executed on receipt of a DC2 code.

Sending an EOT code enables the PC to take the counter out of C mode, and back to the start (default) state.



**Table 2. Counter control function overview.****Line structure:**

Command	Hex code	Description
<b>General control functions</b>		
ENQ	005	Call to set up connection
ACK	006	Command character received o.k. and accepted
NAK	015	After ENQ: call can not be accepted. else: faulty character received
EOT	004	End of communication
SOH	00E	Next character determines the number of transparent characters to follow (usually number of bytes)
RS	01E	Reset

**Control functions from PC to counter**

STX	002	Start of command communication
CAN	018	One function back in command
HT	009	One function forward in command
VT	00B	Pause duration follows
ESC	01B	Reserved
ETX	003	End of command communication
DC1	011	Register follows
DC2	012	Execute command in command memory
DC3	013	Return register set
DC4	014	Return command from command memory
US	01F	Break (interrupt measurement)

**Control functions from counter to PC**

SYN	016	Ready for communication; set up link
SO	00E	Ready for command reception
FS	01C	Receive character, wait for answer
GS	01D	Command memory full
DLE	010	Stop communication; break link

## State diagrams

Figures 9 and 10 illustrate the communication flow between the PC and the counter with the aid of so-called state diagrams. To explain what happens, we take the state diagram in Fig. 9 as an example. All diagrams have a dashed vertical line between the computer side (left) and the counter side (right). The horizontal lines mark intermediate states. An arrow pointing to the PC indicates a character being sent by the counter to the PC. Likewise, an arrow pointing to the counter indicates a character sent by the PC to the counter. The relevant character is found to the left or the right of the arrow. After a character has been sent, a new intermediate or final state arises. Occasionally, an arrow remains at the counter side, while it may also go back to an earlier state. In both cases, a state change occurs that is not caused by the 'other side'. An action can occur (Fig. 10c) during such states.

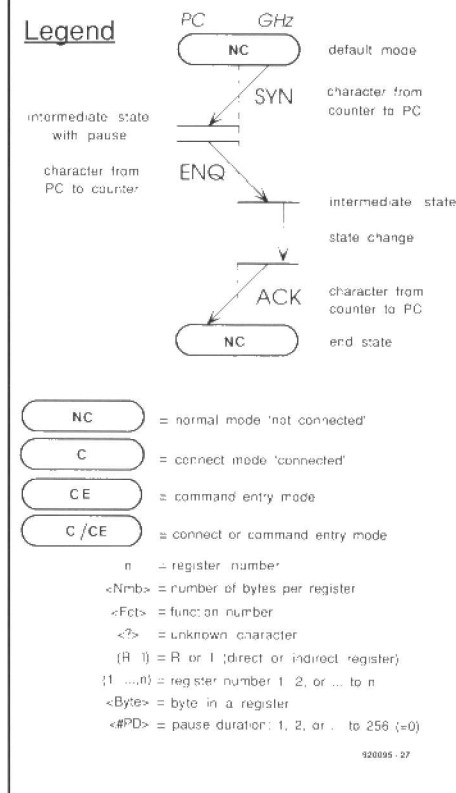
Two parallel lines indicate an intermediate state with a pause, of which the duration may be programmed by control function VT.

Returning to our example in Fig. 9, this can be read as follows: in the default state (not connected, NC), the counter sends a SYN code to the PC. After a short pause, the PC responds with an ENQ code. This prompts the counter to change to connect mode (C), which is confirmed by sending an ACK code to the PC.

If the start or end state in a diagram is marked by 'C/CE' (connect/command entry), the diagram is valid in connect mode as well as command entry mode. Further, the following conventions apply: a register number (1,...,n) is always conveyed as an ASCII number; the number of bytes <Nmb> as a binary value; the register identification (R, I) as an ASCII character; the pulse duration <#PD> and the register bytes <Byte> as binary values.

Figures 10a to 10p show state diagrams for each possible configuration. Figures 10a to 10c illustrate the command strings used to change between the three modes: not connected/default (NC), connect (C), and command entry (CE). In the default mode, the only valid code is an ENQ received from the PC. All other codes received cause the counter to return a DLE,

### Legend

**Fig. 9. State diagram illustrating the communication protocol used between the computer and the frequency meter.**

and refuse to perform the mode change (Fig. 10b).

Whenever the counter transmits more than two characters, for instance, when conveying register contents, or the command string, a 'serial data input overflow' may occur in the PC. To prevent this, the counter has a built-in wait loop, which inserts a short pause between transmitted characters. The pause duration (pacing) can be set to a value between 1 (short) and 256 (long) by the PC (Fig. 10f). After a reset on the counter, or after it is switched on, the pacing is 256.

With some types of measurement, for instance, frequency and revolution counter, the instrument expects a number of parameters, such as the gate time, before the start command. Such a parameter must be written into the relevant register by the PC (Fig. 10g). The register designations are listed in Table 2. Register loading is started by a DC1 code, which can be used to convey only one register (contents), marked by 'R' or 'I' and the associated number (1,...,n). The following is important: the counter transmits <Nmb> (for 'number') in binary code to tell the PC how many characters are expected. The PC must start the message with the lowest-value byte. If, for instance, the counter requests five bytes, the PC must send exactly this number — not more, not less. This



means that the PC may have to transmit nulls. In the case of the above example, assuming that three bytes are sufficient to form a particular value, the PC must still add two null characters to make a total of five bytes.

In connect mode, the **DC2** character

causes the counter to execute the command string received from the PC (Fig. 10h). Depending on the type of measurement, for instance, frequency with a gate time of 10 s, the execution of the string may take some time. The counter acknowledges receipt of the

DC2 code by returning an FS code to the PC. An ACK code follows when the commands have been executed. **Continued next month.**

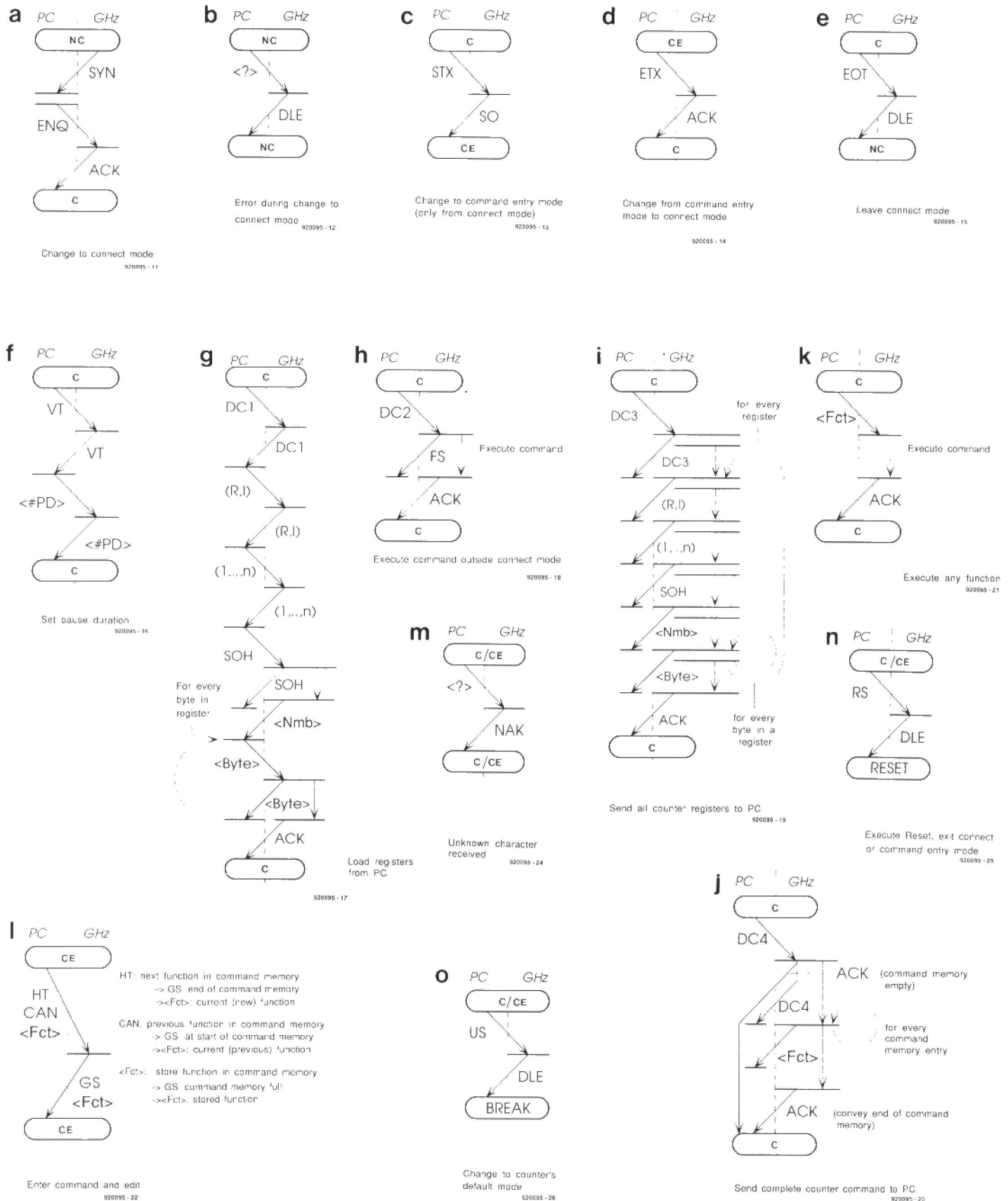


Fig. 10. State diagrams showing how the PC and the counter communicate.

## READERS SERVICES

Except in the USA and Canada, all orders, except for subscriptions and past issues (for which see below), must be sent BY POST to our Dorchester office using the appropriate form opposite. Please note that we can not deal with PERSONAL CALLERS, as no stock is carried at the editorial and administrative office.

**Readers in the USA and Canada** should send orders, except for subscriptions (for which see below), to Old Colony Sound Lab, Peterborough, whose full address is given on the order form opposite. All US\$ prices are postpaid to customers in the fifty states except for books. Please add \$2.00 for the first book and 75c for each additional book ordered. Canadians please add US\$4.50 for the first book, and 75c for each additional one. Canadians may expect Canadian duty charges on shipments of any items except books.

**All other customers** must add postage and packing charges for orders up to £25.00 as follows: UK and Eire £1.75; surface mail outside UK £2.25; Europe (airmail) £2.75; outside Europe (airmail) £3.50. For orders over £25.00, but not exceeding £100.00, these p&p charges should be doubled. For orders over £100.00 in value, p&p charges will be advised.

### SUBSCRIPTIONS & PAST ISSUES

Subscriptions and past issues, if available, should be ordered from **Worldwide Subscription Service Ltd, Unit 4, Gibbs Reed Farm, Pashley Road, TICEHURST TN5 7HE, England**. For subscriptions, use order form opposite. Prices of past issues, including postage for single copies are £2.50 (UK and Eire); £2.80 (surface mail outside UK); £3.00 (air mail Europe); and £3.75 (airmail outside Europe).

### PAST ARTICLES

Photocopies of articles from January 1978 onwards can be provided, postage paid, at £1.75 (UK and Eire), £1.90 (surface mail outside UK), £2.25 (airmail Europe), or £2.50 (airmail outside Europe). In case an article is split into instalments, these prices are applicable **per instalment**. Photocopies may be ordered from our editorial and administrative offices.

### COMPONENTS

Components for projects appearing in *Elektor Electronics* are usually available from appropriate advertisers in this magazine. If difficulties in the supply of components are envisaged, a source will normally be advised in the article. It should be noted that the source given is not exclusive — other suppliers may also be able to help.

### BOOKS

The following books are currently available: these may be ordered from certain bookshops, **Old Colony Sound Lab (USA and Canadian readers only)**, or direct from our Dorchester office.

301 Circuits.....	£8.95.....	\$12.50
302 Circuits.....	£8.95.....	\$12.50
303 Circuits.....	£9.95.....	\$15.90
304 Circuits.....	£10.95.....	\$19.95
Microprocessor Data Book.....	£9.95.....	\$17.90
Data Sheet Book 2.....	£8.95.....	\$16.50
Data Book 3: Peripheral Chips.....	£9.95.....	\$17.95
Data Book 4: Peripheral Chips.....	£9.95.....	\$17.95
Data Book 5: Application Notes.....	£9.95.....	\$17.95

### SHELF BOX

Elektor Electronics shelf box.....	£2.95.....	\$6.00
------------------------------------	------------	--------

### FRONT PANELS

PROJECT	No.	Price (£)	Price (US\$)
Timecode interface	910055-F	8.80	15.00
Digital function generator	910077-F	10.60	18.00
4-Megabyte printer buffer	910110-F	11.45	19.50
Economy PSU	910111-F	10.60	18.00
CD Player	910146-F	12.05	20.50
Measurement amplifier	910144-F	8.80	15.00
FM tuner	920005-F	13.20	22.50
LC meter	920012-F	11.45	19.50

PROJECT	No.	Price (£)	Price (US\$)
Guitar tuner	920033-F	8.80	15.00
NICAM decoder	920035-F	8.25	14.00
12VDC to 240VAC inverter	920038-F	16.15	27.45
Audio DAC	920063-F	10.00	17.00
Dig. audio/visual system	920022-F1	10.00	17.00
	920022-F2	19.40	33.00
	920022-F3	28.80	48.95
1.2 GHz multifunction frequency meter	920095-F	13.80	23.45
<b>U2400B NiCd battery charger</b>	<b>920098-F</b>	<b>8.75</b>	<b>14.90</b>

### EPROMS / PALS / MICROCONTROLLERS

Multifunction measurement card for PCs (1 x PAL16L8)	561	10.30	17.50
Video mixer (1 x 2764)	5861	11.75	20.00
Four-sensor sunshine recorder (1 x 27128)	5921	11.75	20.00
µP-controlled telephone exchange (1 x 27128)	5941	15.30	26.00
RDS decoder (1 x 2764)	5951	15.30	26.00
MIDI programme changer (1 x 2764)	5961	15.30	26.00
Logic analyser (IBM interface) (1 x PAL 16L8)	5971	8.25	14.00
MIDI-to-CV interface	5981	15.30	26.00
Multifunction I/O for PCs (1 x PAL 16L8)	5991	8.25	14.00
Amiga mouse/joystick switch (1 x GAL 16V8)	6001	8.25	14.00
Stepper motor board - 1 (1 x PAL 16L8)	6011	8.25	14.00
4-Megabyte printer buffer (1 x 2764)	6041	15.30	26.00
8751 emulator			
incl. system disk (MSDOS)	6051	29.40	50.00
Connect 4 (1 x 27C64)	6081	15.30	26.00
EMON51 (8051 assembler course) (1 x 27256 + disk 1661)	6061	20.00	34.00
EMON51 (8051 assembler course) (1 x 27256 + disk 1681)	6091	20.00	34.00
Multi-purpose Z80 card:			
FM tuner (1 x 27C256)	6101	20.00	34.00
GAL set (2 x GAL 16V8)	6111	11.15	19.00
Multi-purpose Z80 card:			
BIOS (1 x EPROM 27128)	6121	15.30	26.00
1.2 GHz multifunction frequency meter (1 x 27C256)	6141	11.45	19.45
Digital audio/visual system (1 x 27C256)	6171	10.30	17.50
<b>DIAY system. Package:</b>			
<b>1 x 27512; 2 x GAL; 1 x floppy disk (MSDOS)</b>	<b>6181</b>	<b>30.50</b>	<b>51.85</b>
PAL test pattern generator (1 x GAL 20V8-25)	6211	9.40	16.00
<b>Watt-hour meter (1 x 27256)</b>	<b>6241</b>	<b>10.00</b>	<b>17.00</b>
8751 programmer (1 x 8751)	7061	46.40	70.50

### DISKETTES

Multifunction measurement card (MMC) for PCs	1461	7.65	13.00
8751 programmer	1471	7.65	13.00
PT100 thermometer	1481	7.65	13.00
Logic analyser: IBM software on disk, incl. GAL	1491	19.40	33.00
Logic analyser: Atari software on disk (3.5"), incl. GAL	1501	19.40	33.00
Plotter driver (D. Sijtsma)	1541	11.15	19.00
I/O interface for Atari	1571	7.65	13.00
Tek/Intel file converter	1581	7.65	13.00
B/W video digitizer	1591	11.15	19.00
Timecode interface	1611	7.65	13.00
RTC for Atari ST	1621	7.65	13.00
24-bit colour extension for video digitizer	1631	11.15	19.00
PC controlled weather station - 3 (supersedes disks 1551 and 1561)	1641	7.65	13.00
8051/8032 Assembler course (IBM version)	1661	7.65	13.00
8051/8032 Assembler course (Atari version) (3.5")	1681	7.65	13.00
AD232 converter	1691	7.65	13.00

PROJECT	No.	Price (£)	Price (US\$)
GAL programmer (3 disks)	1701	11.15	19.00
Multi-purpose Z80 card	1711	7.65	13.00
EPROM emulator II	129	6.75	11.50
Pascal library for MMC	1751	9.70	16.50
Speech/sound memory	1771	7.65	13.00
<b>I<sup>2</sup>C opto/relay card</b>	<b>1821</b>	<b>7.65</b>	<b>13.00</b>

### PRINTED CIRCUIT BOARDS

Printed circuit boards whose number is followed by a + sign are only available in combination with the associated software item, and can **not** be supplied separately. The indicated price includes the software.

#### SEPTEMBER 1992

EPROM emulator - II	910082	10.00	17.00
Audio/video processor - 4			ELV project
23 cm FM transceiver			PCB available from author
Audio DAC - 2	920063-2	18.80	32.00
Kerber Klock IV			contact Kerber Klock Ko.

#### OCTOBER 1992

Audio DAC - 3	920063-3	26.45	45.00
8051 SBC			contact Suncoast Technologies
Mains sequencer	920013	17.35	29.50
Wideband active antenna	924101	3.25	5.50
RDS demodulator	880209	5.30	9.00

● Limited supply

#### NOVEMBER 1992

Printer sharing unit	920011	14.70	25.00
Sound sampler for Amiga	920074	6.75	11.50
Difference thermometer	920078	5.30	9.00
Low-power TTL-to-RS232 interface	920127	3.55	6.05

#### DECEMBER 1992

Digital audio/visual system (incl. EPROM 6171)	920022 +	34.10	58.00
1.2 GHz multifunction frequency meter (incl. EPROM 6141)	920095 +	29.40	50.00
Output amplifier for ribbon loudspeakers	920135-1	19.40	33.00
	920135-2	7.95	13.50
Peak-delta NiCd charger	920147	4.10	7.00
<b>Small projects:</b>			
Diskette side chooser	924045		Not available
4-digit counter	924006		Not available
Thermocouple-to DMM interface	924052		Not available
40-W output amplifier	924054		Not available
IDC-to-box header adaptor	924049	6.45	11.00
Mini keyboard for Z80	924047	12.35	21.00
80C552 µP system	924071	20.00	34.00
Speech/sound memory	924012		Not available
60-W music amplifier	924083		Not available
Charging temperature monitor	924066		Not available
Temperature-frequency converter	924020		Not available
Mains power-on delay	924055	6.45	11.00

#### JANUARY 1993

PAL test pattern generator (incl. GAL 6211)	920129 +	15.30	26.00
Dual video amplifier/splitter	920153		Not available
Cross-over point detector	920165		Not available
Multi-core cable tester			
- matrix board	926079	17.05	29.00
- slave unit	926084	6.20	10.55
- master unit	926085	8.25	14.05

#### FEBRUARY 1993

U2400B NiCd battery charger	920098	8.75	14.90
Digital audio enhancer	920169	14.25	24.25
I <sup>2</sup> C opto/relay card	930004	11.00	18.70
Watt-hour meter (PCBs -1 and -2, and EPROM 6241)	920148 +	37.25	63.35



BUYER'S GUIDE TO ELECTRONIC COMPONENTS 1993

# Maplin



BS 5750  
Part 2 1987  
Level B:  
Quality Assurance  
RS12750



**Order your copy of the New MAPLIN Catalogue on sale NOW!**  
Pick up a copy from any branch of WHSMITH or from our chain of shops for just £2.95 or  
post this coupon now to receive your copy for just £3.45 inc. p&p. If you live outside the  
U.K. send £5.50 or 14 IRC's for Airmail in Europe/surface mail outside Europe  
or £10.65 or 27 IRC's for Airmail outside Europe  
I enclose £3.45/£5.50/£10.65 (delete as applicable).

Name.....

Address.....

Post Code.....

Send to Maplin Electronics,  
P.O. Box 3, Rayleigh,  
Essex, England,  
SS6 8LR,  
EK93

**Over 700 product packed pages with  
hundreds of brand new products.  
On sale now, only £2.95**

Available from all branches of WHSMITH and  
Maplin shops nationwide. Hundreds of new  
products at super low prices!